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Case Carbonizing

Case Carbonizing

DRIVER-HARRIS COMPANY
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INTRODUCTION

The rapid growth of the steel industry in the past thirty years has been reflected along all lines of metallurgical work.

The progress has been stimulated at every step by the scientific investigation of the problems involved. This scientific control has resulted in introducing economies in the operation of the older processes and in devising new methods for the attainment of new ends.

It is not surprising, then, to find that, in the field of "Case Carbonizing" or "Case Hardening," a large amount of information has been accumulated which is of value to the heat treater. It is no longer necessary to carry out the process of "Case Hardening" along purely empirical lines. The chemical reactions which are involved in the various methods used for "Case Hardening" are now well understood. The quality of the steel which should be used, the nature of the carbonizing compound, the temperature and time of the operation and the nature of the container have all been subject to investigation.

While this information is to be found in the scientific files, it frequently happens that it is not available to the heat treaters on whom devolves the practical application of the heat treating processes involved.

This booklet, then, aims to lay before the heat treater, in language which can be readily understood, the information which has been rendered available by the more recent scientific investigations.

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CHAPTER I.

CASE CARBONIZING

Definition—History—Mechanics—Oil Tempering vs. Case Hardening—Requirements—Steels—Temperature and Time—Pack Hardening—Carbonizing Compounds—Containers—Packing—Soft Spots—Vertical Pack Hardening.

CHAPTER I.

Case Carbonizing

Definition:

The affinity of iron, and likewise of steel, for carbon is so great that if a piece be heated at a bright red heat for some time, in contact with some material capable of giving up carbon, the iron or steel will readily absorb carbon. If this heating be prolonged over a period of several days, and the amount of carbon absorbed be considerable, then the operation is known as "Cementation." If, however, the operation be of comparatively short duration, say over a period of a few hours, then the operation is known as "Carbonizing" or "Case Hardening." We may therefore say that Carbonizing or Case Hardening is the operation of heating iron or steel, in intimate contact with carbonaceous material, at a temperature above the critical point of the particular steel under treatment, for a short period of time.

In foreign countries the word cementation is used almost entirely when discussing the carbonizing of steel. In the United States the word "Cementation" has come, through common usage, to mean the process of making steel by adding carbon to wrought iron through an absorption operation. For the sake of clearness the words "carbonizing" and "case hardening" will be used throughout this treatise.

As the name "Case-hardening" implies, there are two separate and distinct operations to the process. The first operation produces the case, and the second operation consists of the proper heat treatment of the piece after the case has been

secured. Strictly speaking, therefore, the process commonly known as case-hardening really consists of a case-carbonizing operation and a case-hardening operation.

History:

The process of case-hardening was known to workers in ferrous metals many centuries ago. To state just how ancient the process is, is to go beyond the point of present human knowledge. We do know, however, that the Chinese were familiar with case-hardening as early as the eighth century. It is also known that in the ninth century, a Benedictine Monk wrote a book on case-hardening in which explicit instructions were given as to the correct method for case hardening files. It appears that files and ragged tooth saws were the first implements to be case-hardened. It is interesting to note that the earliest case-hardening of which we have record was done by wrapping the piece to be hardened in a piece of skin which was then burned. This was the forerunner of the charred leather in use to some extent today. The book of the ninth century went so far as to give a formula for the carbonizing compound in which the hardening was to be done, and which consisted of three parts of charred horn to one part of salt.

Since these earliest experiments the process of case-hardening has, of course, undergone many radical changes. The progress was slow during the middle ages, but it has been especially rapid in the last thirty-five years.

Mechanics:

As previously stated, case-hardening is the operation of heating iron or steel in contact with carbonaceous material for a short period of time at a bright red heat. To the practical heat treater, case-carbonizing has come to mean the production of a high carbon surface on a piece of low carbon steel. In

other words, case-carbonizing means the introduction of solid carbon into the surface of iron or steel, or the absorption of carbon by the surface. The high carbon content of the surface is made possible by the mechanics of the carbonizing process. Case-carbonizing is entirely dependent on the fundamental fact that iron or steel will readily absorb carbon at temperatures above the critical point of that particular iron or steel. The correct heat treatment, after case carbonization, gives the necessary hardness to the surface and leaves the core with a requisite softness and toughness, thus making the piece case hardened.

The object of case-hardening can therefore be stated to be: "To produce a piece of steel having the requisite surface hardness to withstand wear and abrasion, and having a core or center, soft and tough to withstand sudden or continued shock."

It is well known that a steel low in carbon is soft, tough, malleable and ductile. A steel of this nature will not withstand wear or abrasion. Conversely, a steel high in carbon is neither soft nor tough, nor is it malleable or ductile; but such a steel will withstand both wear and abrasion. For the moving parts of machines, the combination of the properties of a low carbon steel with the properties of a high carbon steel, should therefore produce a steel well able to withstand wear, abrasion, shock and impact. To secure such a result we must turn to case-hardening, for there we have the high carbon surface to withstand wear and abrasion, and the low carbon core or center to withstand shock, impact and fatigue. In case-hardened steel we have a high carbon surface capable of being heat treated to produce a maximum surface hardness, and a low carbon core which is soft, ductile and tough.

The chemical reaction by means of which case-hardening is brought about cannot be readily explained without entering into a detailed technical explanation, which is outside the scope

of this discussion. It can, therefore, be only briefly touched upon.

Steel, when sufficiently heated, readily absorbs gases. But all gases are not absorbed with equal speed, or in equal quantities. Oxygen, nitrogen, hydrogen, and gases containing carbon are all absorbed, but in varying quantities. Oxygen and hydrogen are absorbed very sparingly, and the steel seems to become saturated very quickly. With gases containing carbon, however, this is not the case. Large quantities of these may be absorbed by the steel by reason of the great affinity of iron and steel for the carbon which is contained in these gases. This fact will be entered into more thoroughly in one of the following chapters devoted to "Gas Hardening." Suffice it to say here, that the mere fact that steel will absorb carbon gases under certain definite conditions is the reason why case-hardening is possible, since it will be remembered that case-hardening is an introduction of carbon into the surface.

Oil Tempering vs. Case-Hardening:

There has been much discussion from time to time as to the relative advantages of oil tempering and case-hardening. It might be well, therefore, to discuss the advantages and disadvantages of the two processes for achieving similar results.

Can oil tempering give the same final results that can be obtained by case-hardening? In order to answer intelligently, it must be understood very clearly that there are important differences between an oil-tempering steel and a case-hardening steel. We have already seen that a case-hardening steel has properties, after heat treating, that are inherent in both low carbon steels and high carbon steels. Consequently, case hardening gives the beneficial effects of both steels.

All metallurgists and heat treaters are familiar with the fact that a low carbon steel cannot be oil-tempered. There-

fore, if oil-tempered pieces are to be produced a rather high carbon steel must be used. On the other hand, it is also a fact that a high carbon steel, after hardening, cannot possibly have a soft or tough core. The comparisons of the two methods of securing a hard wearing surface center around those two basic facts. By the process of case-hardening we obtain the hard surface to withstand wear and abrasion, together with the soft center to withstand shock and fatigue. In oil-tempered stock it is not possible to have a soft core and a hard surface, so we must necessarily come to the conclusion that the use to which the part is to be put must ultimately determine whether case-hardened stock or oil-tempered stock is to be used.

Many laboratories have devoted much effort along different lines to determine the answer to this problem, and most of this investigation work has been done on gears. The subject of "Gear Hardening" will be taken up in its proper place in a later chapter.

Requirements:

Having discussed the fundamentals of case-hardening or carbonizing, we may now proceed with the discussion of the principles on which the results of the case-hardening process depend.

In general, it can be said that the case-hardening process depends on five important factors:

1. Chemical analysis of steel to be case-hardened.
2. Temperature of operation.
3. Length of time consumed by operation.
4. Type of carbonizing material used.
5. Type of container used.

While the process itself is dependent on the five factors enumerated above, the results to be obtained from the case-

hardening operation depend on still another factor, namely: The heat treatment to which the case-hardened piece is subsequently subjected.

A steel high in carbon will resist wear to a greater extent than a low carbon steel. But since a steel high in carbon is capable of being made still harder by the proper heat treatment, it would obviously be unwise to stop after putting the case on the piece to be hardened, when a much harder surface can be obtained by the proper heat treatment. This, then, leads us to the discussion of the steels most often used for case-hardening.

Steels:

The steels most commonly used for case-hardening are low carbon steels with a carbon content of .16 to .22. The impression must not be gathered, however, that only carbon steels are used for this work. Many of the alloy steels are excellent case-hardening steels, and these will be discussed in the proper place. Generally speaking, it can be stated here that manganese, chromium, tungsten, and molybdenum are all elements which, when alloyed with steel, increase the rate of carbonization, while silicon, aluminum, nickel and titanium, decrease the rate.

Since carbon steels are the class of steels most generally case-hardened, they will be discussed first. When the carbon content in steels is more than .25% it tends to increase the brittleness of the steel. The success of case-hardening depends on the fact that it is possible to maintain a very soft core which will also be tough. Therefore, it would be decidedly unwise to start with a steel that has an initially high carbon content, because the start would then be made with a steel having an initial tendency toward brittleness. It must be remembered, however, that steels containing as much as .55% carbon are

used for case-hardening where stiffness and rigidity in the core are more important than softness or toughness.

It might be asked here why steels with carbon contents under the low limit mentioned above are not used, since softness and toughness would be increased. Some foreign manufacturers do use and recommend steels for case-hardening with a carbon content as low as .10. Steels with such low carbon content, however, are more fibrous than crystalline, so that they do not machine easily, and more grinding is necessary than profitable operation will allow. For these reasons the American heat treater has standardized on a .16 to .20 carbon steel. It must always be remembered that the higher the initial carbon in the steel, the greater will be the concentration or percentage of carbon in the case. In this respect the initial carbon is quite important.

The manganese content of a case-hardening steel should not be high, because manganese acts in two ways which are not beneficial. Manganese lowers the critical point of the steel, thereby increasing the degree of overheating that the steel will get during the case-hardening operation. Manganese also increases the brittleness of the case. Good American practice calls for a manganese content under .35%. Although it has been stated that the presence of any appreciable amount of manganese lowers the critical point and increases brittleness, it must not be assumed that a steel with a higher percentage of manganese than .35 is never used for case-hardening. It is sometimes necessary to use a steel which will give the finished product great stiffness. For this purpose a steel having a manganese content of from .75 to .85 is sometimes used. This is especially true of many products made by English manufacturers and particularly of manufacturers in the Sheffield District.

The silicon content of a case-hardening steel should generally be under .25, for the reason that silicon decreases the speed of carbonization and also its depth of penetration.

The phosphorus and sulfur, of course, should be as low as possible, because a case-hardened steel should be exceptionally free from impurities and segregation.

Among the alloy steels, chromium and nickel steels are excellent for case-hardening. Chromium makes the case extremely hard and raises the critical point, thereby raising the temperature at which overheating can occur. Chromium also makes the grain finer and the steel reacts more readily to heat treatment. Chromium up to 1.50% is frequently used in case-hardened steels, but in percentages less than .50 does not seem to have much effect.

Nickel steel is a very good case-hardening steel for several reasons. A nickel steel having a nickel content of from 2.00 to 3.5% is excellent for parts that are important enough to carry the added initial cost of the nickel steel over a carbon steel. Nickel increases the strength of steel, and makes the case less liable to crack by reducing its brittleness. Nickel does not make the steel as hard to machine as does Chromium.

Vanadium, as we would expect from our knowledge of the action of vanadium when alloyed with steel, increases its resistance to fatigue by increasing the toughness of the core.

Temperature and Time:

The next important consideration is the temperature at which the case-hardening is done. On the temperature of operation depends, to a large extent, the depth of penetration; also the percentage or concentration of carbon in the case, and the structure of the core after the operation is completed.

Since temperature of operation and time of exposure to carbonizing influences are interdependent, it will be well to discuss them together. Correct temperatures without a sufficiently long exposure would be as ineffective as long exposure without sufficient temperature.

Case-hardening may be accomplished in any one of three ways, that is, by pack-hardening, liquid-hardening or gas-hardening. We will first make it clear as to what is meant by pack-hardening before proceeding with the discussion of temperature and time elements.

Pack Hardening:

By "pack-hardening" is meant "the operation of putting a high carbon case on a piece of soft steel by packing the steel in a suitable closed container in intimate contact with some solid carbonaceous material, and submitting the whole to a suitable temperature for a short period of time."

The absorption of carbon by a piece of steel during the pack-hardening operation is accomplished by raising the temperature above the critical point of the steel that is being treated. Below the critical point the steel absorbs little, if any, carbon. This is true even though the time of the operation be extended over long periods. Above the critical point, however, the steel has a great affinity for carbon, and the depth of the penetration is greatly increased as the temperature rises higher and higher above the critical point.

It is natural to inquire whether, by increasing the temperature beyond the ordinary temperature at which the operation is done, the time of the operation could not be greatly cut down. The interdependence of temperature and time is one answer to this question, because the higher the temperature the greater the amount of over-heating will be, and although the time be greatly shortened, the bad effects of over-heating will

be present nevertheless, since an excessive temperature coupled with a short time exposure will produce as bad results as a longer exposure at a lower temperature. This bad effect of high temperature and long exposure is known to heat treaters to produce a coarse grain in the core, and as a result the material loses its softness and toughness and gains in brittleness. The second answer to the question is that carbonizing proceeds much more rapidly between 1600° F. and 1650° F. than it does above 1650° F. There are special cases where it is necessary to carbonize at temperatures as high as 1850° F. but such temperatures are the exception and not the rule. It can be taken as standard American practice to case-harden at a temperature of from 1600° F. to 1700° F.

Case-hardening, as stated before, proceeds very slowly, if at all, at temperatures under the critical point of the steel. If it does proceed, it is only a very superficial or surface case. It is therefore clear that if the depth of the case must be very great, a high temperature is absolutely necessary, because a low temperature and long exposure will not produce the desired penetration.

The length of time for which the steel is exposed to carbonizing influences is also important. This is seen from the fact that the time of exposure under constant temperatures is the factor which regulates the depth of the penetration of the case. It follows, then, that by securing the proper depth of penetration, the percentage or concentration of carbon on the surface will also be correct.

One of the fundamentals of case-hardening is that the carbon content of the case varies from the surface inwardly to the core. The surface will have the greatest carbon content, and this gradually becomes less as the case is turned off and the core is reached. The lower the temperature, the shorter the time of the operation, and the lower the initial carbon in the

steel, the greater will be this reduction in carbon content from surface to core.

As the carbonizing process proceeds, that is, as the steel becomes more fully carbonized, additional carbonization requires longer and longer time of exposure. In ordinary case-hardening processes the average rate of penetration is about .80 mm. or .0315 inch per hour.

The production of a case containing more than .9% carbon is never advisable, because cases with more than .9% carbon are liable to crack and spall. This is true for all ordinary work. The production of a very deep case, without causing the concentration of carbon at the surface to be over .9 to 1.0%, can be accomplished by long treatment or exposure at a temperature around 1575° F. This is true notwithstanding the general fact that the concentration of carbon on the surface increases with the depth of the case. If the temperature be high enough, and the time of exposure be sufficiently long, it is easy to carbonize small parts all the way through their diameter, thus offsetting any benefits which the successful case-hardening operation gives.

Substantiating what has gone before, it can be said that the practical heat treater is gradually coming to the viewpoint that low temperature carbonizing gives as efficient results as carbonizing at high temperatures, and that the added time necessary to carbonize at low temperatures is more than offset by the saving in fuel, furnaces, containers, carbonizing compound, and life of the finished article. In addition, the final heat treatment is simpler to perform if the carbonizing has been done at a lower temperature. These elements of cost also tell the heat treater that it is unwise to put a deeper case on the steel than its ultimate use warrants. The cost of straightening case-hardened pieces which have become warped by high

temperatures is another factor in favor of low temperature carbonization.

If there is any exception to the low temperature principle it is only because of very special requirements. For example: It is the practice of one industrial plant to change or oscillate the temperature every two hours during the case-hardening operation. This plant wishes to obtain a surface hardness caused by "cementite" forming in the steel, and brittleness in the finished product is a minor consideration. Generally speaking, however, the lower and uniformly regulated temperature gives the best results.

Carbonizing Compounds:

It may be true that choice of carbonizing compound is not so important as are time and temperature. It is a mistake, however, to consider the nature of the compound as unimportant, and the heat treater who is interested in saving time and keeping down costs should be careful to use compounds containing the proper qualities for carbonizing.

A carbonizing compound is effective only as long as it will release or give up free carbon in one form or another. The term free carbon does not necessarily mean free solid carbon, but rather some gas capable of giving up free carbon upon dissociation. It has been proven that pure, free carbon is not a satisfactory substance for carbonizing, because the length of exposure necessary and the temperature that must be maintained make it unsuitable for present-day manufacturing methods. It can be stated then, that while pure carbon in contact with steel will ultimately carbonize the steel, its use is impractical.

Since it is true that some gas capable of giving up free carbon can be used for carbonizing, we naturally come to the discussion of compounds which will liberate gases containing

carbon. Most compounds that can be depended on for carbonizing are mixtures of some of the following substances, two or more of which are contained in most commercial grades on the market: wood charcoal, ground bone, anthracite coal, ground coke, charred leather, horn, animal black, lamp black, graphite, barium carbonate, sodium chloride (common salt), barium chloride, potassium or sodium cyanide. Ready mixed carbonizing compounds of varying content are sold by manufacturers, so that the heat treater need merely determine which compound meets his particular requirements. Generally speaking, the amount and richness of the carbon gases which they are able to produce should govern the choice of the compound.

All carbonizing compounds, whether granule, flake, or powder, must necessarily have atmospheric air occluded in them when they are packed in a container. Air, of course, is an intimate mixture of oxygen and nitrogen. When the temperature has risen so that action of the free oxygen of the occluded air is possible with the carbon in the compound, carbon dioxide is formed. As the temperature in the carbonizing box rises and approaches the carbonizing temperature, the carbon dioxide gas comes in contact with the red hot carbon in the compound and is dissociated into carbon monoxide, which is the active carbonizing agent. These actions can be clearly expressed in the following two equations:*

C	+	O_2	=	CO_2
Carbon	+	Oxygen	=	Carbon dioxide
CO_2	+	C	=	2 CO
Carbon dioxide	+	Carbon	=	Carbon monoxide

The carbon monoxide then comes in contact with the steel which is packed in the carbonizing compound, with the result that the carbon monoxide is broken up, giving some of its carbon to the steel, which readily absorbs it and thereby becomes

*Note:—If the reader wishes to study these phenomena in detail he should consult Schenck "Physical Chemistry of the Metals." Chapt. IV. & V.

carbonized. This reaction may be represented by the following equation:

2 CO	=	CO_2	+	C
Carbon monoxide	=	Carbon dioxide	+	Carbon

The above, then, is what actually happens in the case-hardening process during the actual carbonizing operation. While practically any carbonizing compound will give the results just mentioned, it will do so only as long as there is free carbon remaining in the compound on which the carbon dioxide gas can act. The compound chosen should therefore contain a large percentage of carbon. For this reason, the same compound should not be used over and over again without being replenished with new material. Good practice calls for a 25% addition of new carbonizing material to each container full of old material, before the old material is again used.

It has been maintained for some time that compounds capable of liberating some free nitrogen are advantageous in case-carbonizing, but this is very doubtful.

While salt is a part of many commercial carbonizing compounds, metallurgists are undecided as to its influence on the actual case-hardening operation. Many practical heat treaters swear by it as an active agent in increasing the speed of carbonizing, but on the whole it may be said that the beneficial effect of salt is doubtful.

Again, there has been a point of difference among metallurgists, for many years, as to the action of barium carbonate contained in some compounds. It has been maintained that cyanides were produced from these carbonates due to the action of the free nitrogen in the occluded air in the compound. It is more probable, however, that carbon monoxide is derived from the carbonate through the carbonate dissociating and giving off carbon dioxide, which later reacts with the hot carbon to form carbon monoxide. The process of case-hardening

through the use of carbon monoxide gas will be thoroughly discussed under the chapter on "Gas-Hardening." The fact that most compounds contain some bone or leather and that they therefore, upon decomposition, give off hydrocarbon gases, is another matter which will be discussed under "Gas-Hardening."

There is one more consideration worthy of mention in connection with the choosing of a compound. Some compounds are capable of carbonizing gradually at low temperatures; that is, at temperatures very little above the critical point, because they give up their carbon gases slowly. These same compounds, at high temperatures, may give off gases entirely too rapidly, thereby greatly increasing the concentration of carbon on the surface of the case-hardened piece. However, compounds which act very quickly are generally used for superficial cases.

Generally speaking, an impure form of carbon is better than pure free carbon for case-hardening, and the fewer the ingredients of the compound, the better the compound will be.

Containers:

Carbonizing boxes or containers, and their relation to efficient carbonizing in the broad sense, will be discussed thoroughly in a later chapter. At this point we are interested only with the size and shape of the containers in relation to the work to be carbonized.

When a packed box is placed into the furnace, the outside of the box and the pieces nearest the walls will naturally arrive at the furnace temperature before furnace temperature reaches the center of the box. This means that the pieces near the walls of the box may begin to carbonize before the pieces in the center of the box reach the critical temperature. The larger the box the greater will be this lag in both time and

temperature, and experience has shown that the lag in temperature may be from two to four hundred degrees. This lag of temperature is always proportional to the size of the box and never can be changed by regulation of the furnace temperature. It is therefore obvious that the box or container should be as small as is possible for manufacturing economy.

Packing:

It is difficult to discuss or lay down any fundamental rules for packing the pieces in the box. Most heat treaters have methods for their particular work which they have learned from long experience. It can be said, however, that even distribution of the packing material around the pieces is very essential. It is also vital that extreme care be taken to pack small or light parts in a box in such a way that they will not carbonize all the way through, thus spoiling the benefits of the case-hardening. If small boxes are not available for carbonizing small parts, then carbonizing compound which has been previously used should be used again, so that the parts which will be on the outside rows in the boxes will not carbonize before the inner rows have reached the carbonizing temperature. Large, heavy parts should be packed in shallow boxes, so that the heat at which the operation is carried on cannot cause them to sag and distort.

Observations and experiences gathered from many representative plants, show that a layer of compound from 1½ to 2½ inches thick, is generally put on the bottom of the box, no matter what kind of material is to be carbonized. Pieces to be carbonized are next put in, placed in even rows or staggered, or in any other suitable manner, care being taken that the pieces do not touch each other or the sides of the box. Good practice calls for at least one inch of carbonizing material between the walls of the box and the row of pieces placed next to

the wall. The depth of the case desired must determine this figure to a great extent, and must also determine the distance or space between each piece.

After the pieces are arranged to the satisfaction of the heat treater, a covering of at least 1½ inches of carbonizing material is put over the pieces before the next layer of pieces is packed in. As many layers of pieces on top of each other as the box size will warrant, can be packed in, if allowance is made for at least two inches of carbonizing material on top of the last layer. Some very careful heat treaters make a practice of using a three-inch blanket of carbonizing material as a cover over the top layer of pieces to be carbonized.

After the box is carefully packed, a metal cover should be put on. It has been customary to make this cover tight by luting with fire clay. Containers are made today, however, which require no luting of this kind, and these will be described in the chapter devoted to a detailed discussion of containers for Pack Hardening.

Soft Spots:

Low carbon spots in high carbon cases are known as "soft spots." These soft spots occur in carbonized pieces wherever the carbon fails to penetrate properly.

Poor packing and poor arrangement of the pieces in the carbonizing box cause soft spots so often that too much care cannot be taken in placing the pieces into the boxes and in packing them in the compound. The pieces should always be evenly surrounded with uniform quantities of the compound, as more carbon may be absorbed where the compound covering is thick and less carbon where the covering is thin. When pieces touch each other, soft spots are sure to occur at the points of contact. Foreign substances in the compound, such as clay, sand or other

solid materials of an inert nature, will cause soft spots if they come in contact with the pieces during the carbonizing process. If an appreciable quantity of sulphur is absorbed during the carbonizing, it tends to produce a soft case.

Since soft spots are caused by failure of the carbon to penetrate at certain spots, it is readily seen that uneven heating and loss of gases through cracks or holes should be guarded against with every possible means.

Uneven heating has a tendency to concentrate the carbon in the case, as well as to make the case of varied depth. Loss of carbonizing gases through cracks or holes in the container is equivalent to uneven heating and is responsible for all kinds of soft spots and spoilage.

It is not always easy to detect pin holes, and even cracks are not always readily seen in their first stages. It is also not easy to determine just to what extent cracking, warping or scaling interferes with heat penetration and carbonizing action. But close study has shown that these conditions are responsible, in very large measure, for the fact that the largest single item of cost in connection with pack-hardening is due to cracking, warping and scaling of the containers.

Soft spots that are the result of poor packing can be eliminated only by proper packing and the foregoing serves as a good general guide. Soft spots, caused by loss of gases due to cracking, warping and scaling of containers, can also be reduced to a negligible point if advantage is taken of the progress that has been made in the development and manufacture of containers. A later chapter will deal very specifically with containers that are proof against cracking, warping and scaling to such a degree that they have proved themselves many times more efficient from every standpoint.

Vertical Pack Hardening:

Before leaving the subject of pack hardening, it is desirable to discuss briefly a comparatively recent development known as Vertical Pack Hardening. This consists of a vertical retort surrounded by a brick combustion chamber, in which the parts to be carbonized are fed through the top along with the carbonizing compound. The parts remain in the retort with the compound for the requisite time at a specified temperature, and are withdrawn at the bottom by gravity. The speed of flow through the retort is controlled by a small trap at the bottom which allows the materials to be withdrawn at any desired speed.

CHAPTER II.

CYANIDE HARDENING

Cyanide Furnaces equipped with Cyanide Pots and Dipping Baskets of Cast Nichrome.

CHAPTER II

Cyanide Hardening

In the preceding chapter, mention was made of the fact that case-carbonizing could be accomplished by any one of three methods, dependent, to a great extent, on the use to which the finished article was to be put. In this chapter the second of the three methods will be discussed under the subject of liquid carbonizers, or specifically, "Cyanide Hardening."

Perhaps the first attempt to case-carbonize by means of a liquid carbonizer, was made by immersing the steel to be carbonized in a bath of molten cast iron. The difficulties of this method were soon evident, and its use was discontinued. However, as study and time were given to the subject of liquid carbonizers, some very good results were obtained, and case-carbonizing by means of a liquid carbonizer is now quite generally employed. The development work made it very evident that high melting point solids must be dispensed with, and so salts that are capable of giving up carbon, and whose melting points are not excessive, were resorted to. Among these salts are the carbonates of sodium and potassium, and the cyanides of sodium and potassium. Other fusible salts have been used, but their use is of comparatively little importance.

There are several marked differences, both in method and in results obtainable, between pack-hardening as described in the preceding chapter, and liquid carbonizing. In the pack-hardening operation the depth of case is directly dependent on the temperature and time. In the liquid carbonizing operation the case produced is superficial or "skin deep." Therefore, the depth of case desired must be one of the determining factors as

to whether liquid carbonizing can be successfully used for any particular job. A few thousandths of an inch is the extreme depth that good practice can secure from liquid carbonizers. In addition to the very superficial case obtained, it has been found that the carbon content does not fall off gradually from the case to the core, but that the difference in carbon percentage is quite marked. This means that the case will have the necessary carbon content for hardening, while just under the case the carbon will be very little higher than in the original steel. This being true, there must be some good reason why liquid carbonizing is used. The best reason is the uniformity of the case obtained and the speed with which it can be secured. Another determining feature is the extreme surface hardness obtainable. Since the case is so very hard and the drop in the carbon content from the case to the core so sudden, it would be supposed that the case might be subject to brittleness and flaking. This is true, and steel should never be case-carbonized in a liquid carbonizer unless resistance to shock, fatigue, impact, etc., is not essential. So it is seen that by using a liquir carbonizer one of the salient features of a case-hardened steel is sacrificed, namely, its toughness and resistance to impact, shock, etc. The liquid method is excellent when these qualities are of secondary importance, and where extreme surface hardness is of primary importance. Extreme rigidity and maximum hardness are the real objects of this process.

The salts most commonly used for liquid-carbonizing are, as stated before, the cyanides of potassium and sodium, which explains why the process has come to be known as the cyanide-hardening process. It must not be supposed, however, that only cyanides are used. Some users mix soda ash (sodium carbonate) and common salt (sodium chloride) with the cyanide.

Whatever salts are used, the theory of their action is essentially the same and depends on the release of a carbon gas

which will give up its carbon to the steel. The principle of the pack-hardening process and the liquid process are therefore the same.

Since cyanides are the essential part of most liquid carbonizers, the method of using it will be taken up in detail. Cyanide hardening can be accomplished in two ways. The piece to be hardened may be immersed in a bath of molten cyanide; or it may be sprinkled with a mixture of cyanide and some adhesive, then heated to the carbonizing temperature and the sprinkling and heating repeated until the desired depth of case is attained. This latter method is known as the "Cyanide Varnish Method." It has some applications, but is not used nearly so widely as the immersion method because it is not as efficient, nor so simple of operation. The immersion method is the one, then, that must be considered.

For the immersion method, an open pot, either rectangular or round, is suspended in a furnace and filled with the salt which, when fused, forms the carbonizing bath. It is impossible to give a standard formula for this salt because the heat treater generally uses one compounded as his experience dictates. Sodium or potassium cyanide alone will do the work but in almost every case some sodium chloride is added, and in some cases a further addition of sodium carbonate is made. One of the largest users of the "Cyanide-Hardening" process used a fused bath composed of 74% sodium cyanide and 26% sodium chloride. Another large user uses a bath of 33% sodium cyanide, 33% sodium chloride and 34% sodium carbonate. The only standard of the whole industry is that cyanide is invariably used. Extraordinary precautions must be taken to have the furnace fumes conducted outside the building, because the gases evolved from molten cyanide are disagreeable and extremely poisonous.

The temperature necessary for carbonizing by this method is very little over the critical point of the steel used, and carbonizing is successfully completed at temperatures from 1450° F. to 1600° F. although temperatures as high as 1750° F. are sometimes maintained. After the bath has reached the necessary temperature, the cold steel to be carbonized is immersed in it and kept in it until it is thoroughly heated to the temperature of the bath. This requires from six to fifteen minutes of time. If a greater depth of penetration than cyanide ordinarily gives is desired, then the time of immersion should be longer, but longer immersion is not advisable because of the danger of creating non-uniform, high carbon spots which might spall and flake in use. Usually, quenching is done immediately after bringing the piece out of the bath, and the quenching is done in either water, lime water or oil.

The distortion and warping is not excessive in this process if ordinary precautions are taken, such as rapid cooling and not too excessive temperatures or too long a time of immersion. The lag or elapsed time between withdrawal from the molten cyanide and quenching in the cooling liquid should be a minimum.

Steel discs, washers, small screw parts, nuts, etc., are successfully hardened in cyanide. In general, parts of small dimensions, or sections are hardened in cyanide because the depth of case can only be a minimum. There is seldom any danger of carbonizing small or thin pieces entirely through when the cyanide method is used.

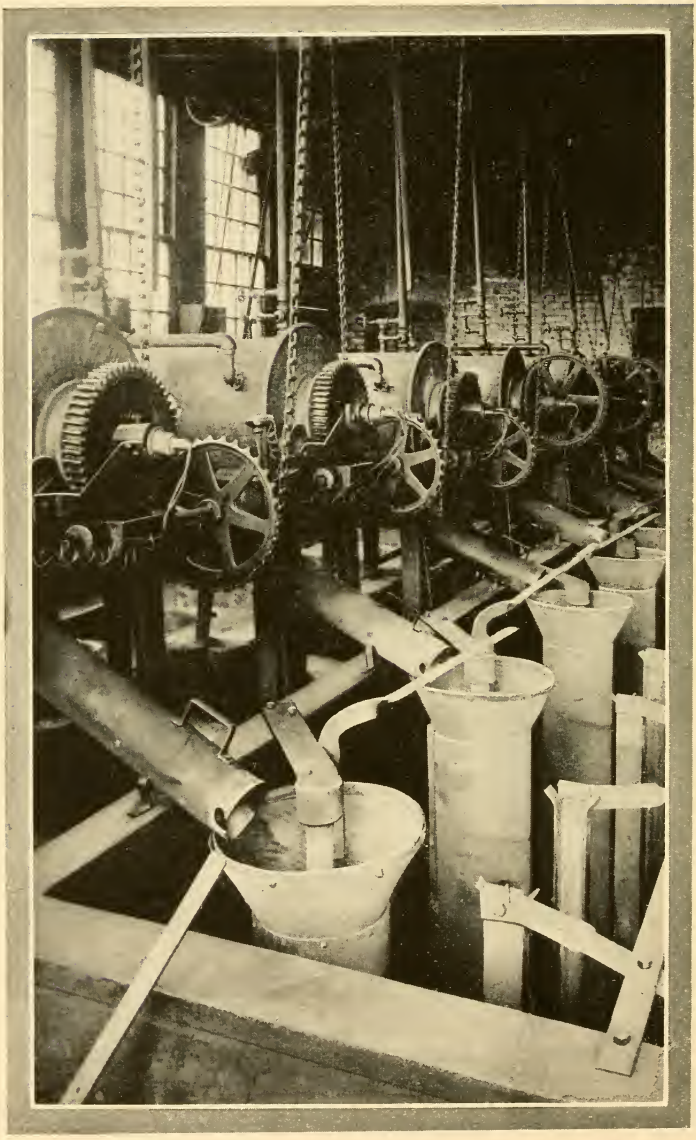
Molten cyanide is very injurious to most containers. Cast iron and steel last but a short time when used in connection with fused cyanides. Oxidation takes place readily, holes burn through the container and large cracks often appear. It is common for the life of an iron or steel container to be as short as fifty hours, although some users obtain as much as 150 hours

from their containers. But aside from the short life of the containers, the worst feature of their failure is that the molten cyanide leaks through the failed container into the furnace, where, if it is not noticed immediately, it ruins the fire brick lining and necessitates a shut down for repairs to the furnace. The consequence, of course, is a loss in production as well as an added cost of production.

Cyanide containers that have overcome these difficulties in very large measure and have multiplied the efficiency many times will be described in a coming chapter.

CHAPTER III.

GAS HARDENING



Gas Hardening Furnaces equipped with Rotary Retorts and Thermo Couple Protection Tubes of Cast Nichrome.

CHAPTER III

Gas Hardening

In this chapter will be discussed the third of the three methods of case-carbonizing.

While it is a fact that in the strict sense of the term, any of the methods of carbonizing could be called "gas carbonizing," gas hardening is commonly used to describe the method of carbonizing in which a gas is employed directly, and in which the steel to be carbonized does not come in contact with a solid or liquid capable of giving up a carbonizing gas. It will be remembered that under the subject of "Pack-Hardening" in Chapter I, the statement was made that all case-carbonizing was due to the action of carbonizing gases. It can readily be understood, therefore, why a free carbonizing gas, rather than a substance capable of liberating a carbon gas, should have some industrial applications.

It might possibly be of benefit to again explain the reactions which take place during the carbonizing operation.

The reactions involved are made possible by the oxygen present in the carbonizing compound or the carbonizing gas. The oxygen comes in contact with the carbon in the compound or gas and forms carbon dioxide, which, as the temperature increases, comes in contact with the red hot carbon and forms carbon monoxide which is the active carbonizing agent. The carbon monoxide then comes in contact with the steel and dissociates again into carbon dioxide and free carbon. The free carbon is absorbed by the steel, and carbonizes it. (See Chapter I. for the reactions.)

Since it is true that the carbon monoxide gas does the carbonizing, it is readily seen that any process which eliminates the reactions necessary for the production of the carbon monoxide during the operation, and supplies the gas directly, would greatly simplify the industrial process.

While it has been said that carbon monoxide is the active carbonizing gas set free by most carbonizing compounds, it should further be understood that carbon monoxide, or any other gas, is active only in proportion to the carbon which it sets free. This carbon is set free and dissolved in the steel in two ways.

Case 1. A gas may dissociate upon contact with the steel and set free all the carbon which it can yield upon the surface of the steel. The carbon thus set free on the surface is gradually absorbed by the steel and penetrates into the steel under the effect of temperature and time. Such a case is rarely met with in practice. It means that the gas evolved acts only as a carrier of the carbon and has no part in the actual carbonization.

Case 2. The second manner of solution of the carbon in the steel is the one which is usually met with in industrial practice. The gas may dissociate in such a way that only a part of the carbon it carries is set free. As it penetrates further and further into the steel the gas sets free more and more carbon within the steel which absorbs it readily. In this instance, such variables as temperature, time of operation, pressure, etc., all have a direct bearing on the case produced. This second manner of gas carbonizing is the method of hardening by means of carbon monoxide. However, at temperatures below 1300° F., carbon monoxide may also act by liberating free carbon on the surface of the steel as mentioned in Case 1. But since such low temperatures are never used in industrial case carbonizing, it can be stated that carbon monoxide acts as explained under the second case above.

Carbon monoxide does carbonize, however, much more intensely if free carbon is present.

The common industrial practice is to use compounds or gases, for carbonizing, which are capable of giving up carbon monoxide, but not all industrial processes depend exclusively on its use. Many applications using gaseous hydrocarbons are in use among the heat treaters, but the specific action of these hydrocarbon gases has been known only within recent times. It is almost certain that part of the carbonizing action of these gases is due to the deposition of free carbon on the surface of the steel as explained under Case I. But all the carbonization done by hydrocarbon gases is not due to this action. Some carbonization is also effected by the absorption of the gas by the steel. A mixture of carbon monoxide gas, with a small percentage of hydrocarbon gas, is an excellent carbonizing gas, and if the percentage of the hydrocarbon is low the action leaves the surface of the steel clean, while increasing the speed of the action.

Mention has been made of the element of pressure in carbonizing. The culmination of all the hopes of the metallurgist has been the production of a process for successfully carbonizing under pressure. It has been shown by a number of experiments that the tendency for steel to carbonize is increased by an increase in the pressure under which the carbonizing takes place. But this is true only within certain limits, so that it is not feasible to carbonize at pressures greater than three atmospheres. While carbonizing is possible at greater pressures, it seems that the rapidity of the operation is greatest at about forty pounds pressure. Successful industrial applications of pressure carbonizing are still in their infancy, but at least one manufacturer of carbonizing equipment has some developments nearing completion for carbonizing by gas under pressure, and

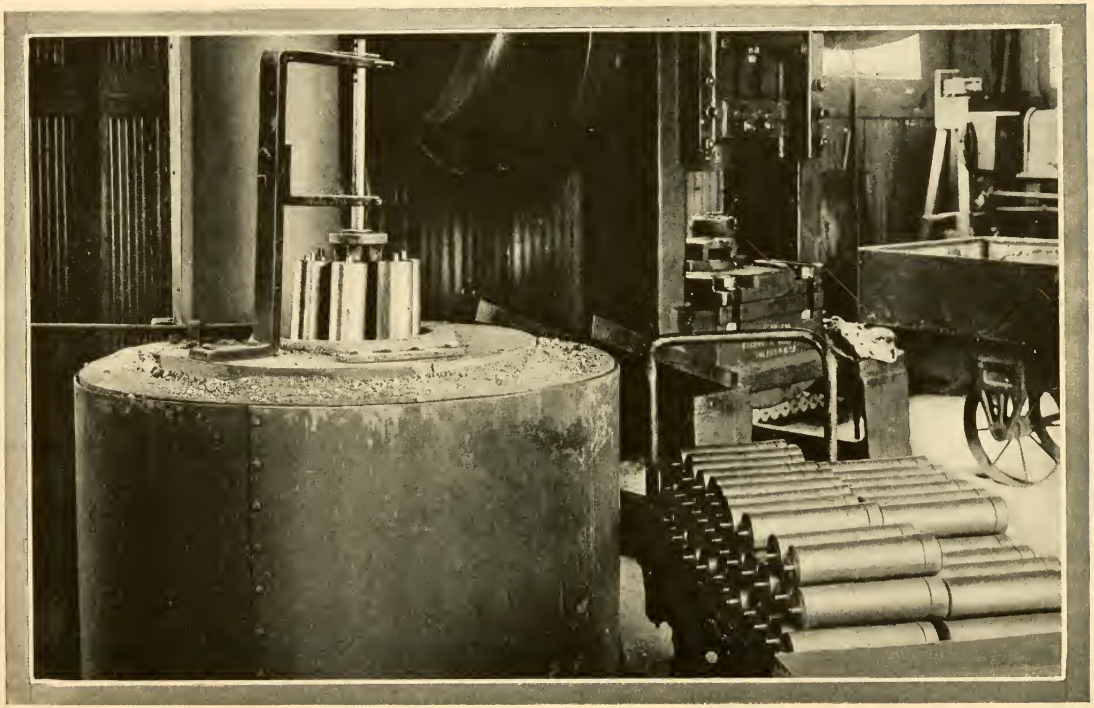
the Driver-Harris Company is now developing a pressure pot for pack hardening under pressure.

Industrial processes for carbonizing with gas consist, for the most part, of a rotary horizontal retort, rotating in a combustion chamber fitted with suitable burner equipment for securing the proper temperature. The pieces to be carbonized are fed into one end of the retort and are discharged at the opposite end after the required time has elapsed. Gas is forced into the retort and as the temperature is correct for carbonizing, the steel absorbs the carbon from the gas very readily. A detailed description of this furnace can be secured from the manufacturers.

Gas carbonizing by this method is feasible for small parts such as bolts, nuts, threaded dies, small axles, bearings, chain links, buckles, etc. The advantages are that large numbers of small parts can be carbonized at one time and that the process is practically continuous. It is especially adapted to securing thin cases. Many large manufacturers of case carbonized parts are now using this process, and its field is practically unlimited.

CHAPTER IV.

LEAD HARDENING



Lead Hardening Furnace with Cast Nichrome Lead Pot.

CHAPTER IV

Lead Hardening

While strictly speaking, lead hardening is not a case-carbonizing operation, the use of lead as a heat-treating medium for case-carbonized parts is extensive enough to make it worthy of mention here.

It was stated in an earlier chapter that case-hardening consisted of two separate and distinct operations—the case-carbonizing operation and the case-hardening operation. In other words, case-hardening consists of the production of the case and the hardening of the case after it has been produced.

The decision as to whether oil, water, or lead should be used for the quenching bath rests to a great extent on the experience of the heat treater and on the kind of work to be heat treated. No standard rules can be set down, and the use of any quenching bath must be ultimately determined by the particular qualifications of that bath. Different manufacturers harden identical parts in entirely different quenching baths. Lead baths have been selected for discussion because the operation involves a rather high temperature, and wherever high temperatures are used difficulties with containers at once follow.

An installation for lead hardening consists of suitable container, supported in a suitable furnace equipped with a proper burner installation to give the required temperature. Containers may be of various shapes, dependent on the kind of work to be hardened. Containers are supplied round, rectangular or of bath tub design. The container is filled with the

lead which, when molten, forms the bath, and a covering of powdered or lump charcoal is added to prevent the surface of the lead from oxidizing. Sometimes a blanket of salt is used instead of the charcoal, but this is not to be recommended.

The only reason for using a high temperature bath is that the object to be quenched or heated is surrounded by a uniformly hot substance on all sides, and is not exposed to the oxidizing influence of the air. Due to the increased cost of heating or quenching by means of lead, its use is confined to work where uniformity and freedom from oxidation and distortion are necessary. However, where uniformity of heating is the only consideration, there is no necessity for using a lead bath, because a well-designed furnace will give a uniform heat. But where it is essential that a bright surface be maintained, a lead bath is indispensable.

Several minor difficulties are encountered in the use of lead. Lead has a tendency to adhere to threaded portions or in holes of the pieces being treated, and may seriously affect the material during the cooling process. On account of its high specific gravity, special means must be taken to keep the pieces that are being hardened or quenched from floating on the surface of the lead, because the steel will not stay underneath the surface of the lead by its own weight. At high temperatures, lead baths give off fumes which must be taken care of, because lead fumes are poisonous. Some manufacturers have found it necessary to agitate the bath from time to time in order to maintain a uniform temperature throughout the container.

The temperatures at which lead baths are used depend entirely on the use to which they are to be put. For tempering, the lead bath is used at temperatures of 650° F. or greater. If it is desirable to use lead for tempering at temperatures lower than 650° F., the melting point of the lead can be low-

ered by alloying the lead with tin or some other low melting point metal.

For hardening, temperatures from 1450° F. to 1750° F. are used, but ranges around 1750° F. are the exceptions and are not to be recommended. Some manufacturers do not consider the use of lead good practice at temperatures higher than 1500° F.

Until recently one of the chief difficulties in the lead hardening process was the failure of containers. A container is now being sold which stands up remarkably well under the severe conditions to which a lead container is subject. This container will be discussed in a later chapter.

CHAPTER V.

CARBONIZING CONTAINERS

Heat Treating Department of a large Bearing Manufacturer using Cast Nichrome Carbonizing Boxes.

CHAPTER V

Carbonizing Containers

The direct bearing that carbonizing boxes, pots, retorts, etc., have on results and on costs cannot easily be overestimated. The use of any container which cracks, warps, scales, etc., is not economical from two standpoints. First, it means that a large surplus supply of containers must be kept on hand at all times. Second, it means that the process involving their use is inefficient, consuming additional fuel, material, labor, etc. The container used also controls, to a great degree, the product produced, and to a greater extent determines the capacity of the plant and the production costs.

It is known to every heat treater that the use of cast iron, wrought iron or steel for containers, is far from satisfactory. Ferrous containers, whether iron or steel, are not suitable for use at temperatures at which they oxidize, and since iron or steel oxidizes at room temperature, their life must naturally be materially shortened at carbonizing furnace temperatures.

When a ferrous container is to be used for case hardening, an experienced heat treater will generally fill it with carbonizing compound and put it into the furnace for several hours. This is for the purpose of impregnating the ferrous container with carbon, so that when it is packed with the pieces that are to be carbonized, all the carbon evolved will not be absorbed by the container, instead of being absorbed by the pieces in the container, as it should be. Preparing the container for service in this manner means the loss of one complete furnace heat. The loss of one furnace heat would be of little importance if it

were not for the fact that this very first heat causes the container to oxidize, forming a scale of iron oxide, and that the life of such containers is very short. Scale formation on the exposed parts of ferrous containers is known as "growth" and occurs invariably when a ferrous container is subjected to high temperature in the atmosphere or in a furnace. This scale, formed as just stated, does more than merely cause a growth of the container. Just as scale in a boiler tube decreases the efficiency of the boiler, so the scale, or iron oxide, formed on a ferrous container, decreases the efficiency of the container, because iron oxide is more or less refractory and interferes with heat penetration. In other words, a portion of the fuel used in the furnace is consumed in driving the heat through the scale, thereby also lengthening the time element without any beneficial result. If the scale which was formed remained in position and protected the ferrous container from further oxidation, the heat treater would learn to judge his time of heats quite easily. But an iron oxide scale is not adhering, nor is it protecting. The scaling or oxidizing does not stop, once the scale has formed, but continues to grow heavier until, of its own weight and due to the difference in expansion under temperature between it and the container, it drops off, exposing fresh surfaces of the container to the oxidizing influences. In this way the container loses weight, grows materially thinner and lighter, and makes it increasingly difficult for the heat treater to produce perfectly carbonized pieces. The container finally becomes so thin or so light, that it is not safe to use it again, due to the danger of burning or overcarbonizing the work contained in it, or because it is so frail that it will not support its normal number and weight of pieces to be carbonized. Besides the foregoing serious defects in ferrous containers, there is also the fact that they crack very easily. Cracks, of course, allow the carbonizing gases to seep through and in this way the parts being heat

treated are frequently damaged and sometimes rendered entirely useless.

It is a custom, when iron or steel containers crack, to lute the cracks with clay, but this is only an expedient and does not remedy the defects. Ferrous containers, then, may be said to fail in almost every imaginable manner. Experience has shown that this is equally true of alloy-steels, as well as of specially designed and cast containers that are made of special grades of crucible or electric steels. It can therefore be stated conclusively that all ferrous containers, whether iron, steel, crucible steel, electric steel or alloy steel, are subject to scaling and will scale in carbonizing temperatures to such an extent that they are far from efficient. The field has been flooded with these so-called heat resisting steels, and failure to get the desired and much-needed relief has made heat treaters wary of special steel and alloy-steel containers. The average life of all such containers is less than two hundred and fifty hours at carbonizing temperatures.

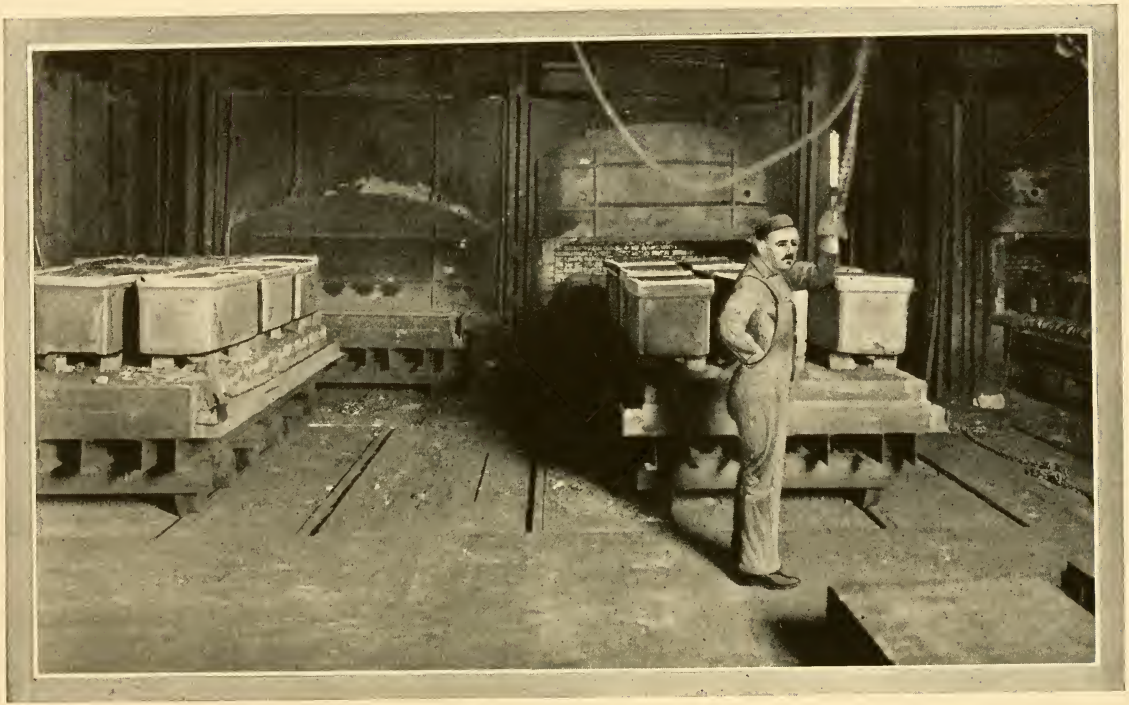
Because of these conditions, the spoilage of expensive materials and the high heat treating cost incident to oxidizing and cracking containers, have been regarded as unavoidable in many heat treating plants. But this was before the alloy known as "Nichrome" was developed and cast into Carbonizing and other heat treating containers. Five years of practical application and use in connection with the most exacting requirements and under the most severe conditions, have proved that Cast Nichrome Containers have solved the problem from every standpoint. Records show that Cast Nichrome Containers give a service of thousands of hours at 1800 degrees Fahrenheit without warping, cracking, scaling or other changes of physical characteristics that interfere with heat penetration. In some cases Cast Nichrome Containers have been in active service for 11,000 hours.

The question as to what this "Nichrome" Alloy is and what characteristics make it succeed where other containers fail, will naturally come into your mind. Therefore, before going into the specific advantages and into the uses to which the various types of Cast Nichrome Containers are put, the next chapter gives some commercial and technical data, as well as a little of the history of "Nichrome."

CHAPTER VI.

NICHROME—COMMERCIAL AND TECHNICAL DATA

Tensile Tests at 70°F. Tensile Tests at 1500° F.



Manufacturers of heavy duty motor trucks use large Cast Nichrome Carbonizing Boxes for crankshaft carbonizing.

CHAPTER VI

Nichrome
Commercial and Technical Data

Alloys of nickel and chromium have been known and used both abroad and in the United States for many years as resistance materials for electrical purposes in the form of wire. The many valuable properties of these alloys are known commercially and technically; detailed information can be found in text books and in a Bulletin published by the Driver-Harris Company of Harrison, New Jersey. Therefore, a brief summary of these properties will suffice here. Resistance to oxidation at extremely high temperatures, uniformity of electrical resistance and conductivity, high melting point, and variety of application, have made Nickel-Chromium Alloys invaluable for electrical purposes. No other resistance material has supplanted them in their particular field.

A number of years ago, the research department of the Driver-Harris Company conceived the idea that "Nichrome," by reason of its resistance to corrosion at high temperatures, might have other valuable industrial applications as a high temperature resisting alloy. Much time and effort was spent in determining these applications and in working out the material to meet them. It was early seen that the demand for such an alloy in the heat treating field was great, so that all efforts were made to produce cast containers to meet the severe requirements of this particular field.

Practical foundry men and metallurgists had asserted that alloys of nickel and chromium could not be successfully cast in

sand. Not satisfied with such results as had been obtained by others, the Driver-Harris Company proved for themselves that the alloy could not be sand cast by ordinary foundry methods. It then became necessary, unless the project was to be abandoned, to devise special foundry practices to take care of the special qualities of the material which was to be cast. For a long time results were indifferent, but as more and more was learned about the alloy and its adaptability, results grew proportionately more encouraging. After many months of continued effort, a process was evolved by means of which it was possible to successfully sand cast the alloy "Nichrome." The demand for these castings became at once established, and their use has been limited only by the facilities for their manufacture.

All the castings made of this nickel-chromium alloy and known as Cast Nichrome are fully protected by patents, owned and controlled by the Driver-Harris Company of Harrison, New Jersey.

Cast Nichrome can be machined readily with any good high speed cutting steel; but due to the toughness of the alloy, the tools must be ground with special angles. These particular angles have been worked out, and blue prints showing how tools should be ground for machining and threading Cast Nichrome can be secured on request from the Driver-Harris Company.

"Nichrome" is a high temperature resisting alloy, being practical for use at all temperatures up to 2000° F. At the high temperatures encountered in commercial practice, "Nichrome" resists oxidation to an extent not possible in any other alloy, steel or iron. Aside from the fact that it is a high temperature resisting alloy, as well as an oxidation resisting alloy, it may be mentioned that it is practically non-warping, retaining its shape almost perfectly at temperatures up to 2000° F. When the castings are properly designed, there should be absolutely no warping or cracking.

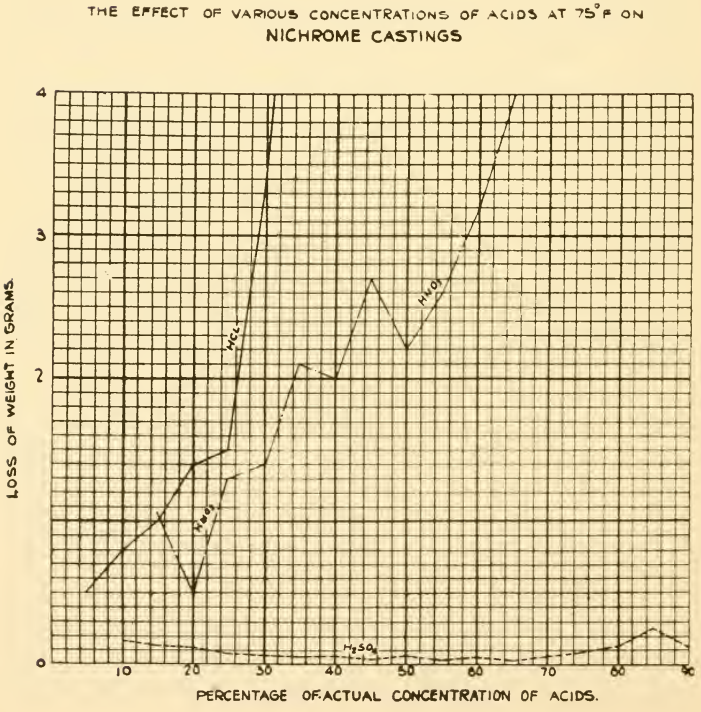
"Nichrome" can be forged at the proper temperature, but must be handled very carefully. It is malleable and ductile, but during the rolling and drawing operations repeated annealings are necessary.

"Nichrome" can be readily welded by experienced welders by either the oxy-acetylene or the electric arc method. The nature of the alloy, however, calls for welders of considerable skill, as a weld on Cast Nichrome cannot be made in the same manner as a weld on cast iron or steel. Pre-heating is almost invariably necessary, and thorough cleaning of the surface to be welded is important. Best results in welding Cast Nichrome are obtained by chipping, with an air or cold chisel, the surfaces of the parts to be welded, so that new, virgin metal is exposed. Welding may be done with or without a flux, depending on whether the weld is a gas weld or an arc weld. If oxy-acetylene is used, then a flux is necessary for good results. If the electric arc is used, a flux is not needed. At the works of the Driver-Harris Company all welding on large, heavy castings is done with the electric arc. It is particularly important that a too prolonged local over-heating does not take place in the welding process as there is grave danger that the weld and the parts around it will become porous and spongy. It is for this reason that thorough pre-heating is necessary.

Cast Nichrome cannot be cut successfully with the oxy-acetylene cutting torch due to the fact that the alloy does not oxidize readily. Since the action of the cutting torch depends on its oxidizing action, it can be easily understood why Cast Nichrome cannot be cut by this means. A good hack-saw or a cold saw is a much cheaper means of cutting the alloy.

The critical point of "Nichrome" is below room temperature and it will not absorb carbon readily until temperatures well over 2000° F. have been reached. Besides its great resistance to oxidation at high temperatures, "Nichrome" is resistant

to the action of most acids and alkalis, hot or cold, and "Nichrome" castings are giving very satisfactory service in a great many applications in conjunction with the use of acids. The curves given below show the resistance of "Nichrome" to the ordinary acids.



The following technical data on Cast Nichrome is given in the hope that it will prove valuable to engineers and technical investigators:

CAST NICHROME

Melting Point	2660° F.
Softening Temperature	2300—2400° F.
Safe Working Temperature	2000° F.
Specific Gravity	8.15
Weight per cubic inch	.29 lbs.
Specific Heat	.111 at 100° C.
Brinell hardness with 1000 Kilo weight	160—170
Brinell hardness with 3000 Kilo weight	179
Sclerescope hardness	27 to 30
Coefficient of Linear Expansion over temperature ranges:	
From 0 to 100° C.	.0000121 per ° C.
From 32 to 212° F.	.0000091 per ° F.

Thermal conductivity is 0.0341 calories per centimeter per second or in a ratio of 1 to 4.88 of soft iron. Expressed in percentage 20.5% of the thermal conductivity of soft iron. Tests made on a 1″ diameter specimen.

Tensile Tests at 70° F.

Elastic Limit	40,000 lbs. per sq. in.
Ultimate Tensile Strength	54,000 lbs. per sq. in.
Per Cent. Elongation	1%
Per Cent. Reduction of Area	2½%

Tensile Tests at 1500° F.

Elastic Limit	20,100 lbs. per sq. in.
Ultimate Tensile Strength	24,500 lbs. per sq. in.
Per Cent. Elongation	4%
Per Cent. Reduction of Area	4.3%

TABLE I

Temperature	Tensile Strength in Pounds per Square Inch			
	Cast Iron	Wrought Iron	Mild Steel	Cast Nichrome
70° F.	18,000	42,000	55,000	54,000
500° F.	18,000	48,000	70,000	
1000° F.			15,300	
1100° F.	10,400			
1500° F.	7,600	6,300	9,900	24,500
1800° F.				15,000
2000° F.				12,000

TABLE II

Temperature	Percentage Change of Normal Strength at 70° F.			
	Cast Iron	Wrought Iron	Mild Steel	Cast Nichrome
70° F.	Normal	Normal	Normal	Normal
500° F.	None	11½% Inc.	27% Inc.†	
1000° F.			72% Dec.*	
1100° F.	42% Dec.*			
1500° F.	58% Dec.*	85% Dec.*	82% Dec.*	55% Dec.*
1800° F.				72% Dec.*
2000° F.				78% Dec.*

NOTE—* Dec. means decrease. † Inc. means increase.

While the results shown in the two preceding tables are subject to some changes (due to the varying compositions of cast iron, wrought iron, and steel), the figures given show conclusively the superior tensile properties of Cast Nichrome at high temperatures. It is also clearly evident that "Nichrome" is a much better engineering material for high temperatures than iron or steel, because of the fact that its tensile strength at 1800° F. is as great as the tensile strength of mild steel at 1000° F., and almost as great as the tensile strength of cast iron at 70° F.

Cast Nichrome will bend considerably without breaking at either a red or a white heat. The metal does not become easily fatigued. This fact can be readily demonstrated by supporting a plate of Cast Nichrome ¾″ thick at the four corners, and striking the unsupported center with a heavy sledge.

CHAPTER VII.

CAST NICHROME CONTAINERS

Cast Nichrome for Cyanide Hardening—Cast Nichrome for Lead Hardening—Cast Nichrome for Pyrometer Protection Tubes—Dipping Baskets—Additional Uses for Nichrome Castings.

Cast Nichrome "SEALTITE" Pots are used in this up-to-date Plant.

CHAPTER VII

Cast Nichrome Containers

In a preceding chapter it was stated very emphatically that "Nichrome" did not scale at temperatures well above the range of case carbonizing processes. The fact that "Nichrome" does not scale was learned in early experiments, and was the primary cause of the development of Cast Nichrome for carbonizing containers. Since no scale is formed at carbonizing temperatures, the walls of Cast Nichrome containers can be made thin and the container itself will then be correspondingly light in weight, while leaving to the heat treater the assurance that his container will not go to pieces in the furnace. Not forming a scale, Cast Nichrome containers require no more temperature to produce equivalent results, in subsequent heats, than was required for the first heat. Not forming a scale, the weight of a Cast Nichrome container is constant, so that a heat treater is assured of comparable results from every heat.

The life of Cast Nichrome containers is exceptionally long, being from thirty to fifty times as long as the life of any ferrous container under the most severe furnace conditions. It is not necessary to maintain a reducing atmosphere in the furnace to secure long life from Cast Nichrome containers. On the contrary, a slightly oxidizing atmosphere is preferable.

Users of Cast Nichrome carbonizing containers can attest to the fact that the life of these containers at a temperature of 1800° F. runs into thousands of hours. Records are on file in the offices of the Driver-Harris Company proving that one large user of Cast Nichrome Containers has secured as much as

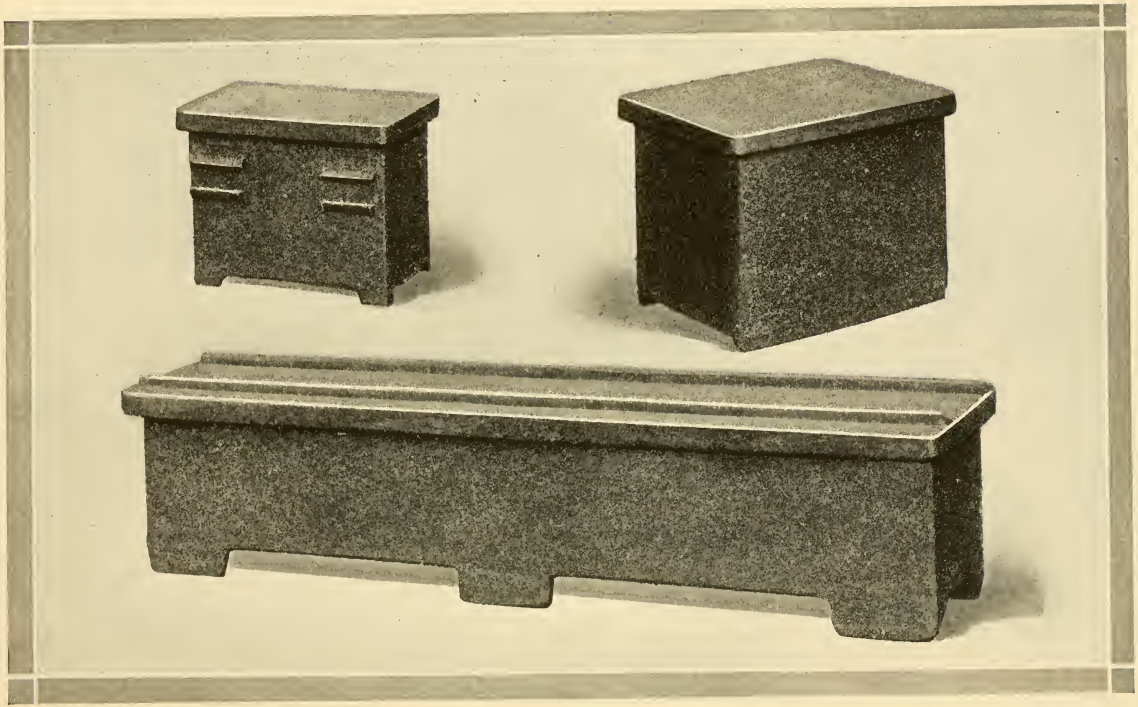


Fig. 1. Cast Nichrome Carbonizing Boxes with "shoe box cover."

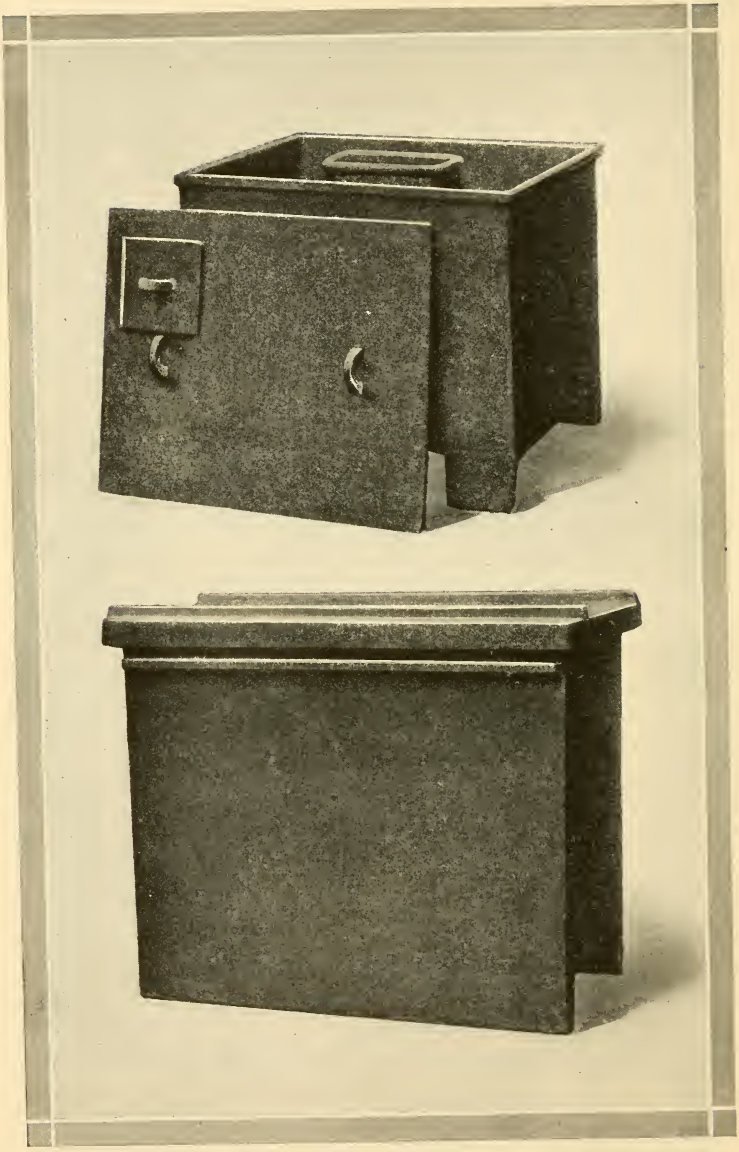
eleven thousand hours from some of his containers. The average life generally is between five thousand and seventy-five hundred hours' service under average conditions.

The fact that Cast Nichrome Containers are tougher and stronger at elevated temperatures allows thinner castings to be made of this material. As a consequence the heat travels through the walls of the container much more quickly and considerable fuel is saved.

One of the largest case-carbonizing plants in the middle West, using low sulphur producer gas for fuel, has shown by accurately kept log sheets, that by the substitution of Cast Nichrome Containers for steel containers the fuel consumption per furnace was reduced from 420 cubic feet per hour to 265 cubic feet per hour, effecting a saving of 155 cubic feet of producer gas each hour of operation per furnace. Because of the rapidity of the heat penetration through Cast Nichrome Containers, the length of heats for this concern was reduced from nine hours to six and one-half hours, thus effecting a saving of two and one-half hours for each furnace per heat. These figures are authentic, and the name of the company from which they were secured will be given on request.

All heat treaters know the trouble experienced from the cracking and warping of ferrous containers. Cast Nichrome does not crack or warp, so that the heat treater knows positively that he will always be able to put the same number of containers in the furnace heat after heat, and is further assured that the covers for the containers will fit throughout the life of the containers.

Since Cast Nichrome Containers do not scale, crack, or warp, they can be made in designs not feasible with ferrous containers. Cast Nichrome rectangular pack hardening boxes are made with a cover which fits the box much as a shoe box lid fits the box itself. This container, commonly known as the "shoe



Figs. 2, 2A. Cast Nichrome Open-Chimney Carbonizing Box with test hole and cover. (Bottom)—Cast Nichrome Carbonizing Box with lifting lugs and runners instead of legs.

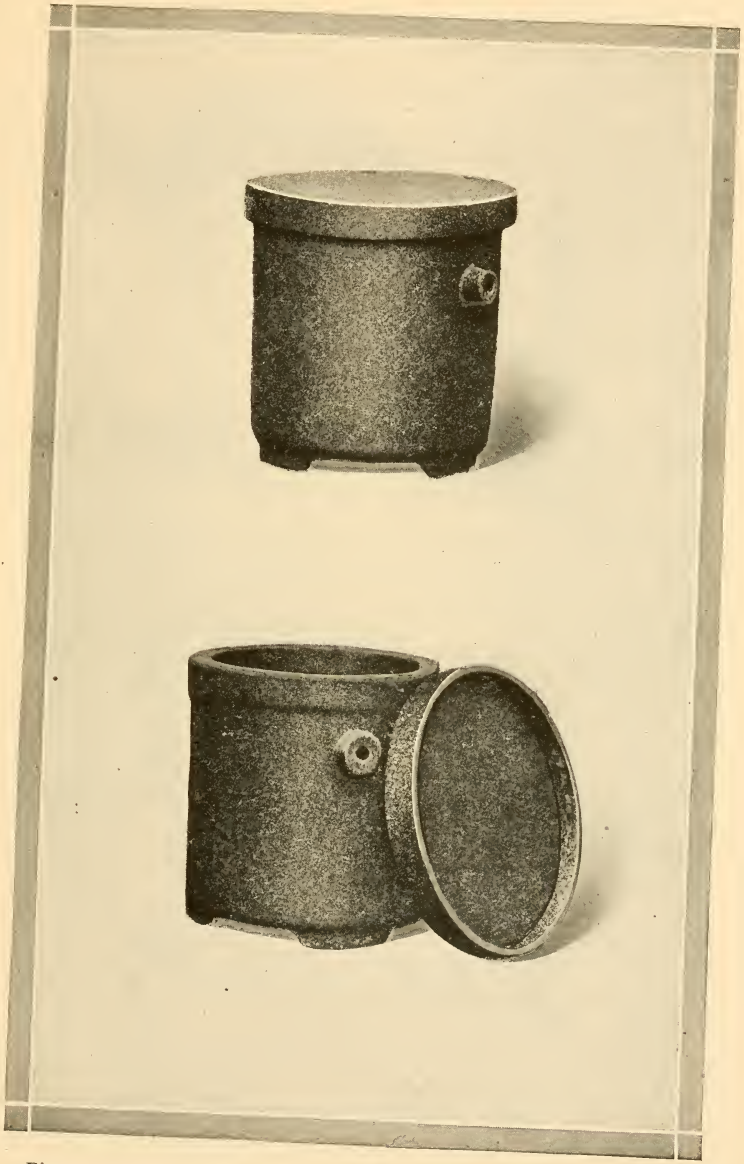


Fig. 3. Cast Nichrome Carbonizing Pots with "shoe box cover" and lifting lugs.

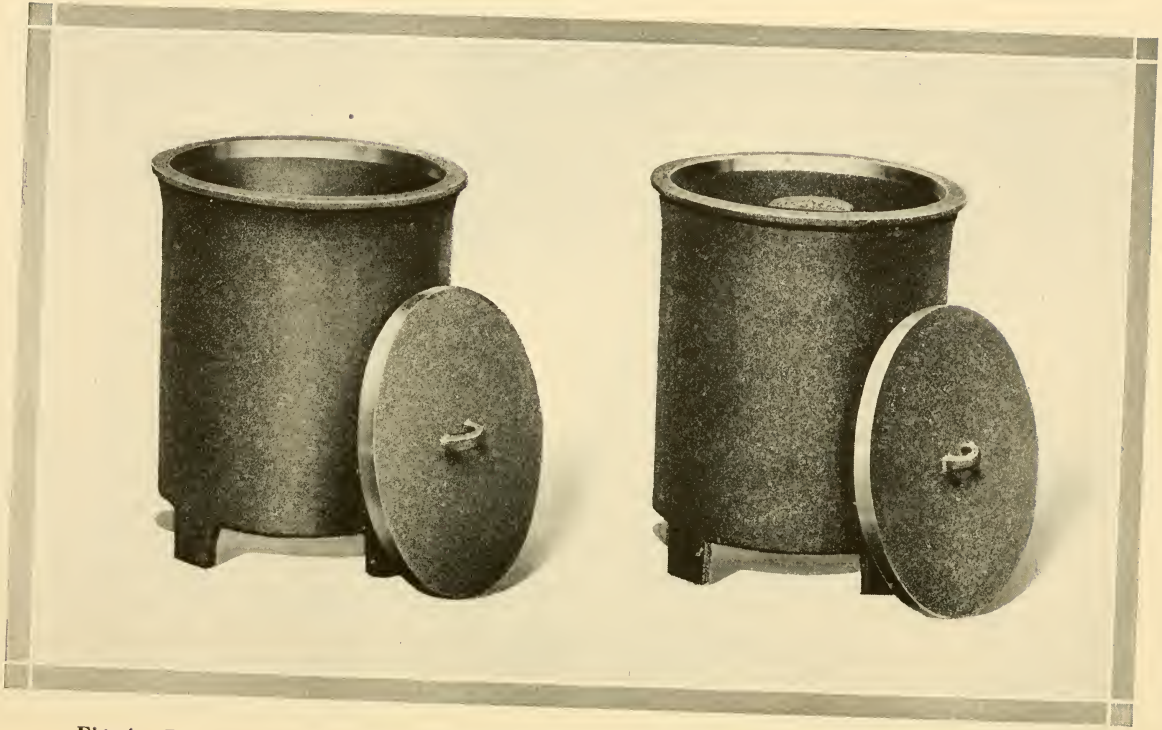


Fig. 4. Patented "SEALTITE" Carbonizing Pot of Cast Nichrome—with and without chimney.

box cover" design, is sold to the user with the assurance that the cover can be replaced on the box, after any number of heats, as easily as when the container was delivered new. Also, owing to this particular design, the efficiency of the container is greatly increased in that a positive pressure, so beneficial to carbonizing, is always maintained. Less fire clay luting is required (some users have discontinued the use of fire clay with this container), and there is no ashing of the carbonizing materials. Due to the toughness of the alloy itself, no particular care is necessary in handling the containers.

The "shoe box cover" container is shown in Fig. 1, page 66. A detailed, mechanical sketch is shown in the Appendix, together with a list of the standard sizes of this container, the patterns for which are kept in stock by the Driver-Harris Company, Harrison, New Jersey.

For many classes of work to be case-carbonized, heat treaters have found the rectangular box unsuitable. Therefore, the Driver-Harris Company has designed a round Cast Nichrome Container made with the "shoe box cover," and from which the same excellent results can be obtained. This round box is shown in Fig. 3, page 69. The sizes of this Cast Nichrome Container, for which patterns are kept in stock by the Driver-Harris Company, are given in the Appendix, together with a mechanical sketch of the container.

The fact that Cast Nichrome serves for thousands of hours at 1800° F. without warping, cracking or scaling has led to the invention and patenting of a Cast Nichrome Container which is unique in the heat treating and case carbonizing industry. This Cast Nichrome Container is a round container with a machined, taper fit cover, which fits tightly into the container and effectually closes the container, much as a ground glass stoppered bottle can be tightly closed by a simple turn of

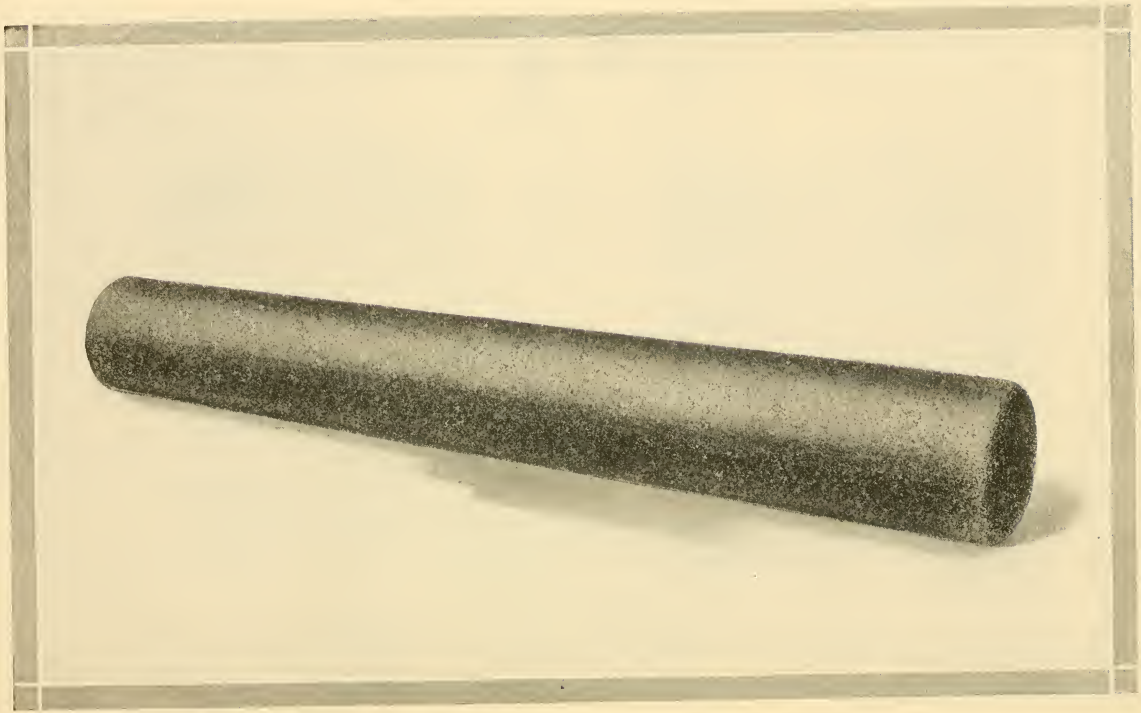


Fig. 5. Closed-end Tube of Cast Nichrome.

the stopper. Such a container would not be possible with any other material but "Nichrome." This fact is self-evident because a container that scales or warps could not possibly be expected to maintain a tapered seal after the first heat. Cast Nichrome does not scale or warp, so that the machined cover fits the taper of the container as well after several thousand furnace hours as when the container is first used.

This patented container is known as the "Sealtite" pot, and is used by many of the largest case-carbonizing plants in the United States. There is absolutely no luting required with this design pot, the seal formed by the seating of the machined cover in the machined container being tight enough for any carbonizing operation. In addition to its longer life this Cast Nichrome "Sealtite" container is from fifteen to twenty per cent. more efficient than any ferrous container. Pressure, due to liberated carbon gases, in this type of container, may be developed to such an extent as to blow the cover off the pot. This has been the experience of one large user, who blew off the covers many times before he became convinced that the gases were being generated in his pots faster than they could be absorbed. When he was finally convinced that a great saving in compound was possible by the use of this Cast Nichrome "Sealtite" Container, he was able to save some fifteen per cent. of his fuel, cut his time by one-quarter, and do away entirely with any luting of the pots.

This "Sealtite" Container is shown in Fig. 4, page 70, and stock pattern sizes, together with a mechanical sketch of the container, are shown in the Appendix. This type of container is also made in the "chimney-pot" design for the carbonization of ring gears, large ball races, etc.

Annealing tubes and carbonizing tubes of Cast Nichrome are made with one end closed and with the other end threaded, so that a "Nichrome" cap can be screwed on, thus effectually

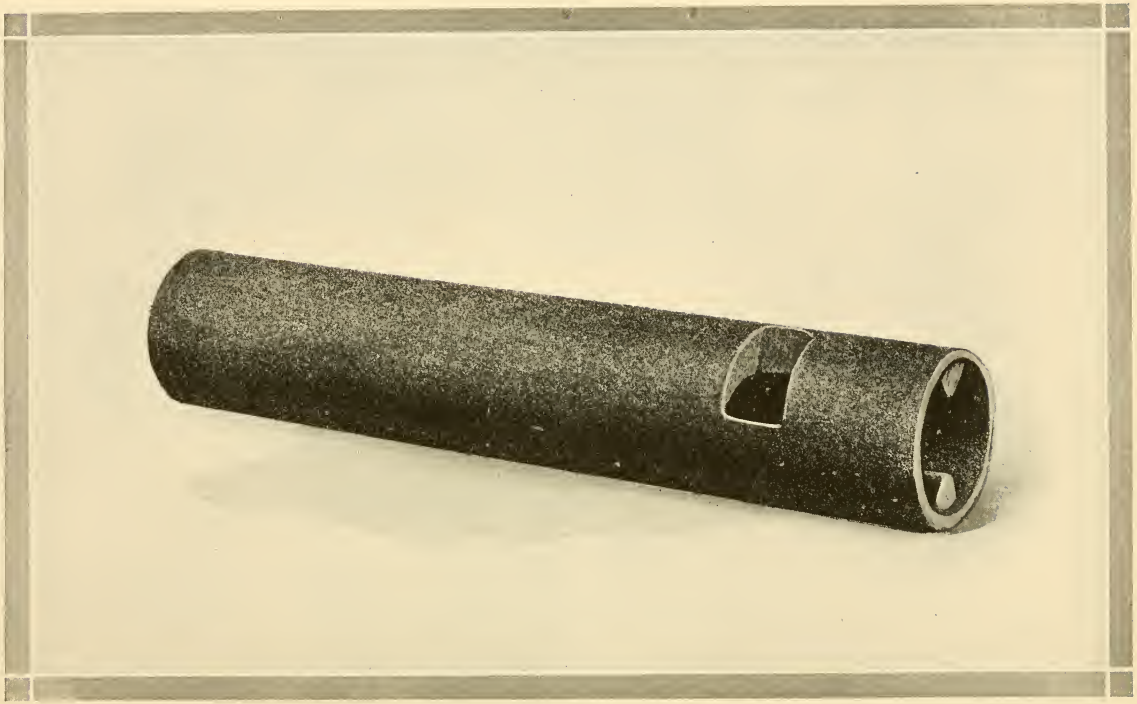
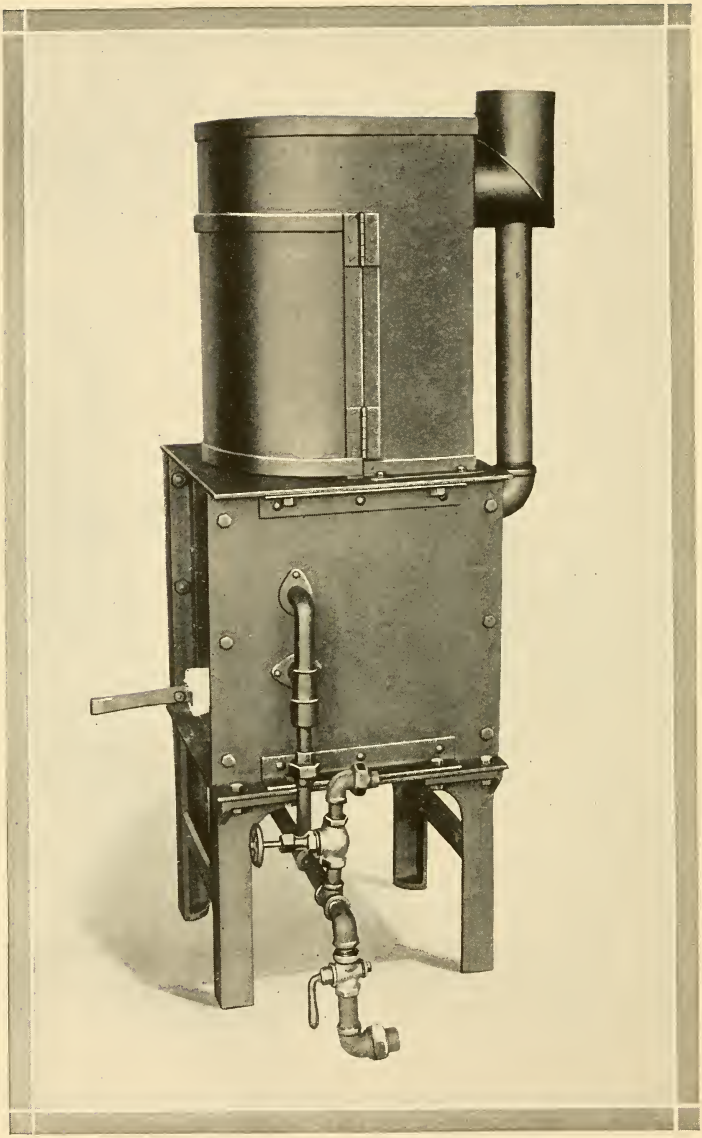


Fig. 6. Rotary Spiral Cast Nichrome Retort.

closing the tube. These tubes are used in many large industrial processes, such as the ball-bearing industry, the cam shaft industry, and in the treatment of wire for incandescent lamp manufacture. Many standard patterns for these tubes, pictured in Fig. 5, page 72, are kept in stock by the Driver-Harris Company.

It was stated in the chapter devoted to Gas Hardening, that the principal part of the Gas Hardening Machine is a rotating retort. Until the introduction of Cast Nichrome Retorts in the industries, these rotating retorts were always made of a ferrous material giving a life of from three to four weeks at the temperatures necessary for carbonization. Since the introduction of Cast Nichrome Retorts, users have been able to secure a life of from eighteen months to two years from each retort at temperatures of 1700° F. to 1800° F. The saving effected in labor, furnace repairs, fuel, production, time, etc., by these Cast Nichrome Retorts, has led to their adoption as standard equipment by one of the largest gas hardening furnace manufacturers in the United States. These retorts can be made in any size and weight up to five thousand pounds. More than sixty retorts weighing twenty-five hundred pounds each were supplied to the Gas Defense Division of the United States Army during the recent World War, and were operated at a temperature of 2000° F. in the production of Gas Mask Carbon. When it is further understood that these Cast Nichrome Retorts operated in an atmosphere of superheated steam, the remarkable non-oxidizing qualities of the alloy will be appreciated. Cast Nichrome rotary retorts are effecting great savings for some of the largest steel ball manufacturers.

They are made to specifications either as a straight cylindrical retort, or as a spiral retort for continuous furnace operation.



Cyanide Furnace with Carry-off flue.

Cast Nichrome for Cyanide Hardening:

Users of liquid carbonizing containers, such as cyanide pots, are well aware of the difficulty encountered in securing a satisfactory ferrous container. The use of Cast Nichrome containers effectually solves this problem and assures the heat treater thousands of hours of continuous service, without the exasperating delays due to the container springing a leak and necessitating its removal from the furnace. Where the furnace life of a ferrous container may be from 50 to 150 hours, no extraordinary skill is necessary to secure from fifteen to twenty times this service from a Cast Nichrome container. At the temperatures used for cyanide hardening, Cast Nichrome is as resistant to the action of the molten cyanide, as it is to oxidizing influences at temperatures of pack-hardening.

The Research Department of the Driver-Harris Company has found that the most efficient and economical cyanide furnace is one in which the cyanide pot is sealed into the furnace by means of a seal of chrome ore or magnesite. The seal is placed between the brick lining and the flange of the pot. In this type of furnace the waste gases of combustion are led into a separate flue, and there is, therefore, no connection between the combustion chamber and the hood which covers the cyanide pot. This method of construction effectually prevents the cyanide vapors from passing into the combustion chamber. Since it has been proven that cyanide in the combustion chamber greatly reduces the life of a pot, the life of Cast Nichrome Cyanide Pots, under conditions just outlined, should be long enough to show marked economy.

Besides the great lengthening of pot life by this furnace construction, there are the added advantages of a large saving of cyanide, an increase in the life of the furnace lining, and a more even temperature.

Fig. 7. Large Lead or Cyanide Pot—Cast Nichrome.

Cast Nichrome for Lead Hardening:

Heat treaters, who prefer to harden in molten lead, have experienced the same difficulty with ferrous containers as have the cyanide hardening users. Cast Nichrome containers solve the lead container problem effectually and assure the heat treater many thousands of hours' life at the average temperature of lead hardening. Round, rectangular, and bath tub shaped lead pots are made of Cast Nichrome in all sizes and weights, from a small pot of five or ten pounds for cutlery hardening, to a large Cast Nichrome bath tub of two thousand pounds for the automobile industry. Covered Cast Nichrome rectangular lead pots, for continuous wire-tempering furnaces, are used by the largest wire manufacturers in this country. Figs. 7, 8, 9 and 10 show Cast Nichrome cyanide and lead containers, and stock sizes will be found in the Appendix.

Cast Nichrome for Pyrometer Protection Tubes:

Cast Nichrome pyrometer protection tubes need no introduction to American industry. For some years they have been standard equipment of the leading pyrometer manufacturers. Their superiority to ferrous tubes is so well established that no comparison is needed. From one to two years' continuous service under the most severe conditions of temperature and fuel, have established Cast Nichrome pyrometer protection tubes in the plants of the world's manufacturers.

They are made in many designs and innumerable sizes, and can be supplied plain, threaded, flanged, light walled, or heavy walled, dependent on the conditions for which they are supplied.

Cast Nichrome pyrometer protection tubes are shown in Fig. 11, page 83, and stock pattern sizes are listed in the Appendix.

Fig. 8. Cast Nichrome Lead or Cyanide Pots.

Fig. 9. Cast Nichrome Lead Bath Container—Tub Design.

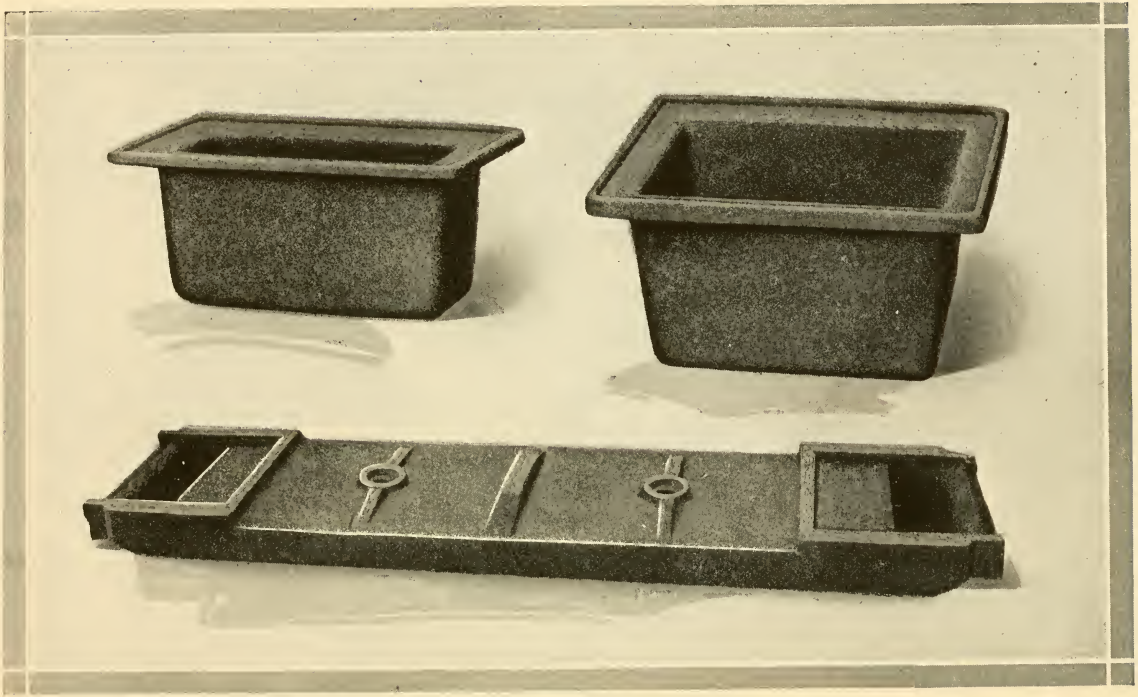


Fig. 10. (Top)—Cast Nichrome Lead Pots—rectangular. (Bottom)—Covered Cast Nichrome Lead Pot for continuous wire tempering.

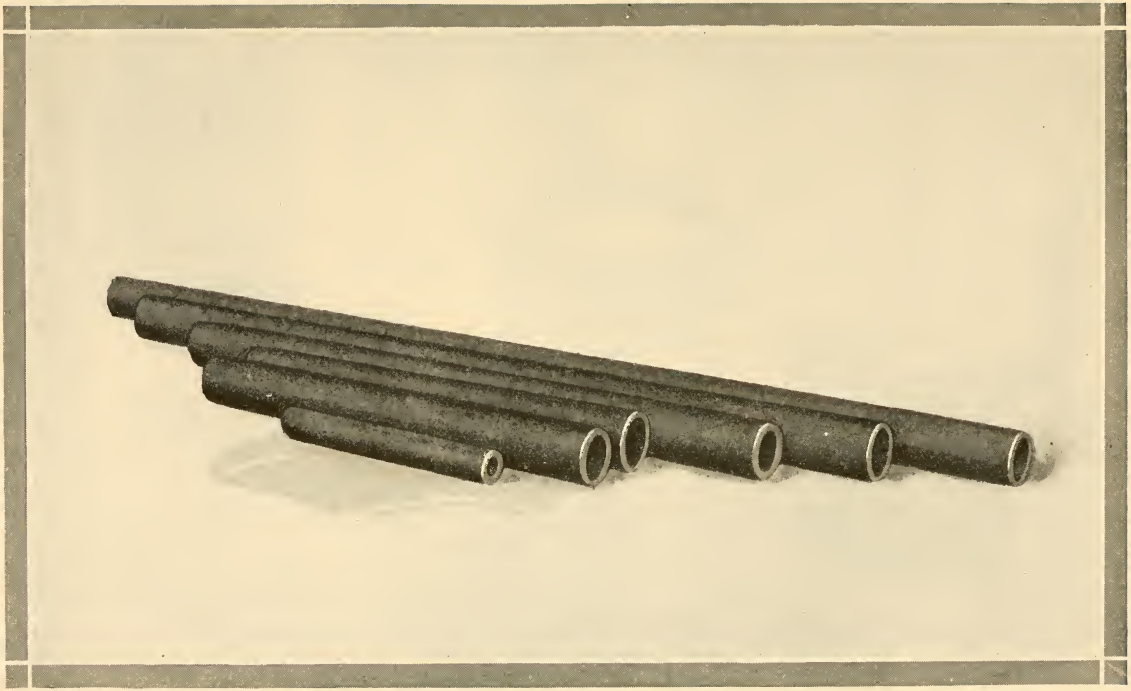


Fig. 11. Cast Nichrome Pyrometer Protection Tubes.

Fig. 12. Cast Nichrome Dipping Baskets for cyanide hardening.

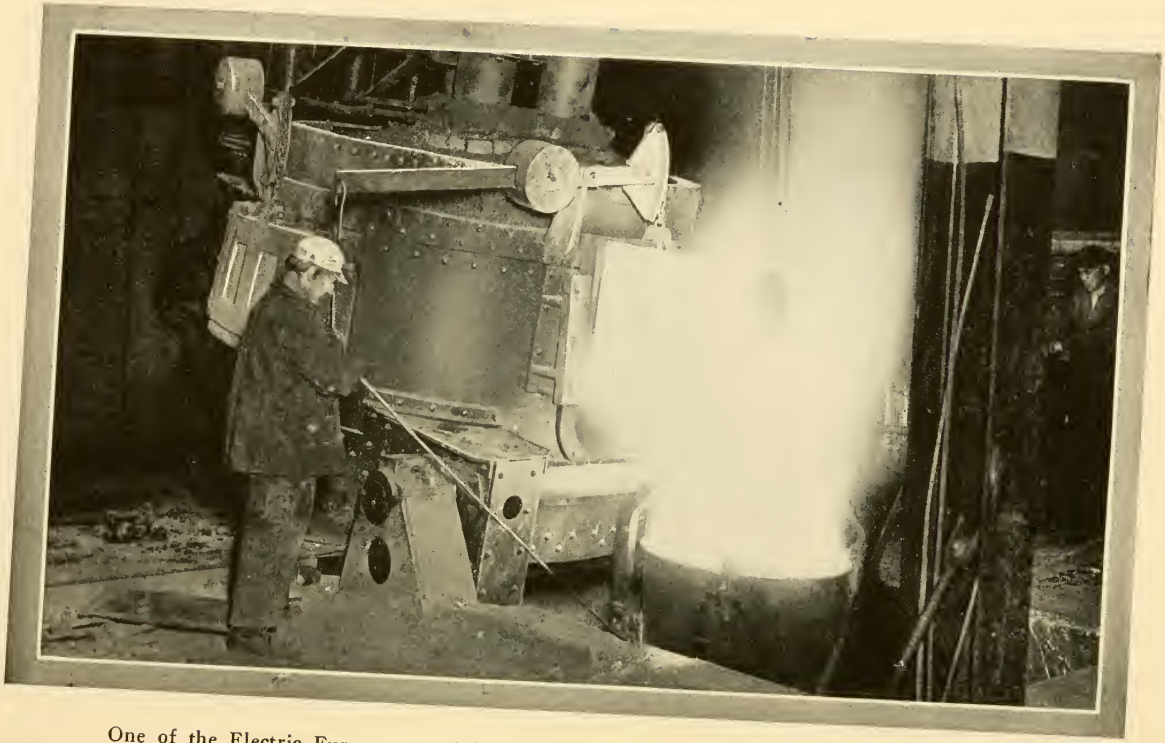
Dipping Baskets:

One of the most important industrial applications of Cast Nichrome is the "dipping basket" used for the purpose of immersing small parts in a molten cyanide bath or for immersing small parts in heat treating quenching baths or pickling baths. Its life under these rigorous conditions is practically endless, as it shows no tendency to grow, shrink, warp, or crack. Many large automotive manufacturers have entirely replaced their ferrous basket equipment with Cast Nichrome baskets. Fig. 12 shows the types of Cast Nichrome dipping basket most commonly used.

Additional Uses for Nichrome Castings:

Cast Nichrome has a wide range of other industrial uses, such as glass molds for the glass bottle industry; molds for the die casting industry; conveyor baskets and chains for continuous furnaces of many kinds; furnace parts; muffles for ore-roasting, etc.

The Driver-Harris Company maintains an engineering department to which inquiries as to the adaptability of Cast Nichrome for industrial purposes other than those which are ordinary fields, can always be referred.

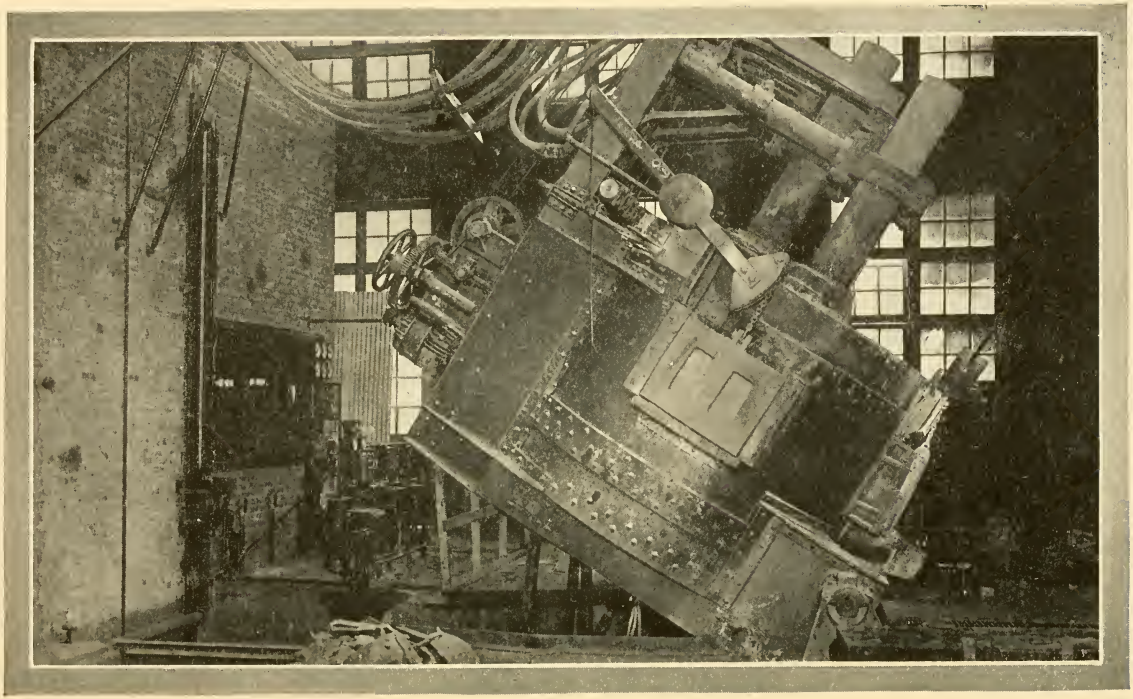


One of the Electric Furnaces, used in making Cast Nichrome, beginning to pour a heat.

CHAPTER VIII.

COMMERCIAL METHODS OF USING CAST NICHROME

Automobile Starting and Lighting Equipment—Studs—Set Screws—Small Bolts—Nuts—Screws—Etc.—Ring Gears for Automobile Differentials—Roller Bearings.



Showing position of Electric Furnaces when pouring of heat is completed.

CHAPTER VIII

Commercial Methods Of Using Cast Nichrome

It has been stated elsewhere in this book that the use of Cast Nichrome containers offers many advantages to the heat treater, among them being a saving of fuel, and therefore of furnace repairs; a saving in time of operation; a saving in labor costs; a saving in production costs; greater production from the same furnace equipment; and a greater uniformity in product. Since these advantages are so marked, and since data is available from so many large manufacturers using Cast Nichrome containers, a brief outline of carbonizing methods used in representative plants of the several industries doing carbonizing is given here in the belief that these methods will effect similar savings for others who may not be using Cast Nichrome containers.

Automobile Starting and Lighting Equipment:

Under this head are included small shafts, cams, ball races, sprockets, etc. The pieces to be carbonized are packed in Cast Nichrome carbonizing boxes of the "shoe box cover" or "Sealtite" design. Both styles of containers can be advantageously used for this class of work. The size of the container should be determined by the size of the furnace and by methods available for handling. No fire clay luting is necessary. Hydrocarbonated bone black, hydrocarbonated lamp black or any other good carbonizing compound can be used. The containers, packed with the pieces to be carbonized, are placed in the

furnace and subjected to a temperature of 1700° F. for six and one-half to seven hours, if the parts to be case-carbonized are made of .20 carbon steel. If they are made of a 3.5% Nickel-steel, the temperature need not exceed 1650° F. At no time is it necessary to run temperature over 1700° F. for this small work.

After the case-carbonizing operation is completed, the boxes are drawn from the furnace, covers removed, and contents allowed to cool. Then the carbonizing material is riddled out. The pieces which have been carbonized are then reheated to 1475° F. and drawn at 400° F. If shafts of a carbon content of 40% have been carbonized, the reheating temperature should go as high as 1550° F. and the drawing should take place at 350° F.

Studs, Set Screws, Small Bolts, Nuts, Screws, Etc.:

Material of this nature is carbonized in a cyanide bath in a Cast Nichrome container, and immersed in the cyanide bath by means of the Cast Nichrome dipping basket. For best results, a bath of cyanide made up of equal parts of salt, soda ash, and sodium cyanide is excellent. The temperature need not be over 1500° F. and the time of immersion should be about twelve minutes. After the carbonizing operation, the material should be quenched as quickly as possible in oil or water.

Ring Gears for Automobile Differentials:

Gears of this type are effectually carbonized in Cast Nichrome Sealtite Chimney Pots. The compound used for carbonizing is made up into a paste and mechanically pressed into the teeth of the gear. The gears are stacked one on the other and placed carefully in the Cast Nichrome container. Temperature of carbonization is 1700° F. and 3/32″ case is obtained in eight or nine hours.

Small pinions which cannot be stacked conveniently are carbonized in Cast Nichrome closed end tubes in which the pinions are placed and packed with a loose compound. They are carbonized at a temperature of 1700° F. in eight to nine hours.

After the carbonization is complete, the gears are taken to a reheating furnace without being allowed to cool. The reheating should be done at 1500° F. and the time of treatment should be one hour. When a temperature of 1500° F. has been maintained for one hour, the gears are quenched in oil. In order to make certain that both the case and the cover have been refined, a second reheating to a temperature of 1400° F. should be given the gears, and a second oil quenching should follow.

Another method of treatment of ring gears is to carbonize in Cast Nichrome "Sealtite" pots with loose compound at a temperature of 1600° to 1650° F. for ten hours. The gears are allowed to cool in the pots. When cool they are thoroughly cleaned and the subsequent reheatings for heat treatment is done in molten lead contained in Cast Nichrome lead pots.

It is possible to quench differential gears directly from the carbonizing box, and then give one subsequent reheating in lead. In this way, one reheating is done away with.

Roller Bearings:

Roller bearings are carbonized in Cast Nichrome rectangular carbonizing boxes, and the cups and covers are similarly carbonized in Cast Nichrome "Sealtite" Pots with a gas seal cover. The length of heat is fourteen hours, and the temperature is 1600 to 1650° F. The long heat is made necessary by the depth of case which is desired. The rollers of the roller

bearing, after carbonizing, are cooled in the boxes and then reheated in large Cast Nichrome rotary retorts, the operation being continuous. The rollers, after passing through the retort, are discharged into an automatic quenching device.

APPENDIX.

STOCK PATTERNS AND SPECIAL CONTAINERS

The widely varying requirements and operating conditions in case carbonizing and other heat-treating processes call, of course, for engineering practice in applying the proper containers. The Driver-Harris Engineering and Research Organizations are constantly co-operating with the men responsible for results in the heat-treating departments of the various industries.

Such service naturally brings with it a broad experience, as well as a number of standardized designs which have proved their efficiency and which can be used in many heat-treating plants.

The tables on the following pages show some of the stock patterns and sizes in which Cast Nichrome Containers are made.

CARBONIZING BOXES

A	B	C	D	E	F	G	H	K	Weight of Box—Estimated	Weight of Lid—Estimated	Pattern No.
All dimensions in inches									In lbs.		
*5⅛	5⅛	3 9/16	¼	¼	6¼	6¼	4		7¾	3	1001
6	3	2	¼	¼	7⅛	4⅛	3	½	5	2½	1002
6⅛	4⅛	4⅛	¼	¼	7 5/16	5 5/16	5⅜	¾	12	4	1152
7	7	2½	¼	¼	8¼	8¼	3½	½	10	5	1004
7	7	7½	5/16	5/16	8⅜	8⅜	8 3/16	¾	26½	7	1005
*8	5⅝	10	⅜	⅜	9½	7⅛	11⅜	¾	41	7	1006
8	6	5	5/16	5/16	9⅜	7⅜	6 5/16	¾	20	7	1007
8¼	5¾	6 7/16	5/16	5/16	9⅝	7⅛	7½	½	25	7½	1008
*8½	5¼	3	¼	¼	9⅝	6⅜	3 15/16	½	12	4¾	1143
8½	5½	3	¼	¼	9¾	6¾	4	½	12¼	6¾	1110
L8½	6½	3¼	¼	¼	9¾	7¾	3¾		13	10	1009
8½	7	4½	5/16	⅜	9⅞	8⅜	5⅞	¾	24	10	1010
8½	7	6 5/16	5/16	5/16	9⅞	8⅜	7⅛	¼	26	8¼	1133
8½	7	6½	5/16	5/16	10	8½	7⅞	¾	27	11½	1011
9	7¼	8½	⅜	⅜	10⅝	8⅞	9 15/16	¾	43	13	1012
9	9	8¼	5/16	5/16	10⅜	10⅜	9 9/16	¾	45	9	1013
9⅛	5⅛	7 3/16	¼	¼	10⅜	6⅜	8¼	½	22	7½	1014
L9¼	6¼	2½	¼	¼	10½	7¼	3		11½	7¼	1015

*9⅝	7¾	6½	5/16	5/16	11	9⅛	9 13/16	¾	32	9½	1016
*10	5	7½	⅜	⅜	11⅝	6⅝	8 13/16	⅝	38	11	1017
*10	5¼	5	5/16	5/16	11⅜	6⅝	6 3/16	⅝	23	8	1132
10	5½	4 1/16	5/16	5/16	11½	6⅞	5⅜	¾	20	8½	1018
10	6	8⅝	⅜	⅜	11½	7½	10	¾	43	13½	1019
10	6	10	⅜	⅜	11⅝	7⅝	11 7/16	¾	46	13½	1020
10	6¾	6 9/16	5/16	5/16	11½	8½	8 7/16	1¼	30	12½	1128
10	7	6	5/16	5/16	11⅜	8⅜	7 5/16	¾	28½	10	1151
10	10	10	7/16	7/16	12	12	11 9/16	¾	73	23	1021
10	10	17	½	½	12½	12½	19⅜	1	135	23	1022
10⅛	8⅛	9	⅜	⅜	11¾	9¾	10 7/16	¾	54	14	1023
*10¼	7	6⅝	5/16	5/16	11⅝	8⅜	7 11/16	½	31½	9¾	1024
*10½	6	2½	5/16	5/16	12	7½	3⅝	½	16½	11¼	1103
10½	8½	2⅞	5/16	5/16	12	10	4	½	21½	14½	1161
*11	7	2½	¼	¼	12¼	8¼	3		16	11	1174
*11⅜	6	4½	5/16	5/16	12⅞	7⅜	5⅞	¾	28	13¼	1025
L11⅜	7⅜	3 11/16	5/16	5/16	12⅞	8⅞	4 5/16		24	14	1026
11½	7	6½	⅜	⅜	13⅛	8⅝	7 15/16	¾	40	15	1027
*12	6¼	7¼	⅜	⅜	13⅝	7⅞	8 11/16	¾	44	14½	1130
12	7	5½	5/16	5/16	13½	8½	6⅝	½	31	14	1100
12	8	8	⅜	⅜	13⅝	9⅝	9 15/16	1¼	53	14	1029
12	9	7	⅜	⅜	13⅝	10⅝	8 7/16	¾	51	16	1031
R12	9	9	7/16	7/16	13⅞	10⅞	10 9/16	¾	68	17½	1032
R12	10	11	⅜	½	13⅝	11⅝	12 9/16	¾	80	18	1033
L12⅛	4⅛	4 1/16	5/16	5/16	13½	5½	4⅝		19½	8	1034

(Continued)

CARBONIZING BOXES (Cont'd)

A	B	C	D	E	F	G	H	K	Weight of Box—Estimated	Weight of Lid—Estimated	Pattern No.
All dimensions in inches									In lbs.		
*12⅛	6⅛	5¾	⅜	⅜	13¾	7¾	7 3/16	¾	38	14½	1035
*12⅛	6¼	6¼	⅜	⅜	13¾	7⅞	7 15/16	1	43	14	1036
12⅛	12⅛	19 1/16	½	½	14⅝	14⅝	20 7/16	1½	168	30	1145
12¼	10¾	6	⅜	⅜	14	12½	7 7/16	¾	54	22	1037
*12½	6¼	9	⅜	⅜	14⅛	7⅞	10 7/16	¾	55	15½	1038
13	4½	5¼	5/16	5/16	14⅜	5⅞	6 9/16	¾	27	9	1119
13¼	9¼	8⅛	7/16	7/16	15	11	9⅝	¾	72	20½	1039
L14	6	6	⅜	⅜	15⅝	7⅝	6 11/16		41	15	1041
14	8	8	⅜	⅜	15⅝	9⅝	9¾	1	65	17½	1042
14	9	5	⅜	⅜	15⅝	10⅝	6 7/16	¾	45	19	1043
*14	10	10	½	½	16¼	12½	12⅜	1½	108	27	1044
14¾	7½	5¾	⅜	⅜	16⅜	9⅛	7 3/16	¾	47	18	1045
15	6⅛	8	⅜	⅜	16⅝	7¾	9 7/16	¾	50	15	1046
15	7	8	⅜	⅜	17⅛	9⅛	9 7/16	¾	58	20	1106
15	9	13	½	½	17½	11½	14⅝	¾	132	30	1047
15	15	6	7/16	7/16	17⅜	17⅜	8 1/16	1¼	90	42	1048
15	15	8	½	½	17½	17½	9⅝	¾	121	42	1109
15¼	8¼	8 9/16	7/16	7/16	17½	10½	10 9/16	1¼	76	23	1049

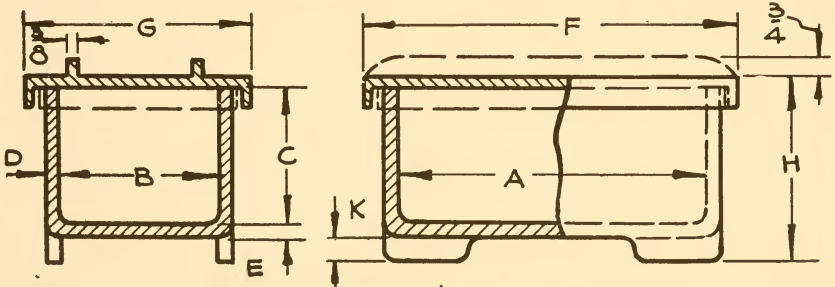
15¼	9¼	4¾	⅜	⅜	17⅜	11⅜	5 15/16	½	53	23½	1050
15¼	12	14¼	½	½	17¾	14½	16⅜	1¼	160	37	1052
15⅜	6¼	6⅞	⅜	⅜	17⅝	8½	8⅝	1	50	23½	1140
15⅜	8¼	11½	½	½	18	10⅞	13 1/16	¾	113	24	1053
15½	11	11½	½	½	18⅛	13⅝	17 7/16	2	131	42	1054
L15¾	6¾	5⅜	⅜	½	17⅞	8⅞	6 3/16		51	18½	1055
15¾	8	12	7/16	7/16	18⅛	10⅜	13 3/16	1	116	28	1056
16	5	5	⅜	⅜	17⅝	6⅝	6 7/16	¾	41	17	1057
16	7⅛	8 5/16	7/16	7/16	18⅜	9½	9⅞	¾	76	27	1113
*16	7⅝	10 7/16	7/16	7/16	18⅜	10	12	¾	92	27½	1058
16	8	6	7/16	7/16	18¼	10¼	7¼	½	58	28	1059
*16	8	10½	7/16	7/16	18⅜	10⅜	12 1/16	¾	99	28	1162
15⅜	6	6	⅜	⅜	17	7⅝	7½	¾	50	16	1175
16½	6	5⅞	7/16	7/16	18¼	7¾	7⅜	¾	54	18	1060
17	9	8	7/16	7/16	19½	11½	9½	¾	82	27	1061
17	11	11	½	½	19½	13½	12⅝	¾	142	38	1062
17⅛	6⅝	10½	7/16	7/16	19½	9	12 5/16	1	99	26	1064
18	6	11	7/16	7/16	20⅜	10⅜	12 3/16	¾	100	35	1065
18	10	4½	⅜	⅜	19¾	11¾	6¾	¾	55	36	1066
18	11½	11½	½	½	20½	14	14⅝	1½	155	40	1063
18	12	10	½	½	20½	14½	12⅜	¾	138	42	1067
L18	18	9½	½	½	20½	20½	11⅛		169	59	1068
*19	10¼	10½	½	½	21	13	12⅞	¾	134	40	1069
20	7¾	5	⅜	⅜	21⅞	9⅜	7¼	¾	51	36	1070
20	10	10	½	½	22¾	12¾	12⅜	¾	132	40	1071

(Continued)

CARBONIZING BOXES (Cont'd)

A	B	C	D	E	F	G	H	K	Weight of Box—Estimated	Weight of Lid—Estimated	Pattern No.
All dimensions in inches									In lbs.		
*20	12	8	1/2	1/2	22 1/2	14 1/2	10 3/8	3/4	125	48	1072
*22	11	11	1/2	1/2	24 1/2	13 1/2	13 3/8	3/4	163	51	1073
22	16	11	9/16	9/16	24 3/4	18 3/4	13 1/2	3/4	220	81	1075
L22	22	10	9/16	9/16	24 3/4	24 3/4	11 3/4		256	95	1076
23	7 1/2	11 1/2	1/2	1/2	25 1/2	10	14 3/8	1 1/4	146	42	1123
23	11 1/2	11 1/2	1/2	1/2	25 1/2	14	14 5/8	1 1/2	188	53	1077
24	8 1/2	9 1/2	1/2	1/2	26 1/2	11	12 1/8	1	142	48	1176
24	10	10	1/2	1/2	26 1/2	12 1/2	12 1/8	1/2	155	51	1078
24	12	12	9/16	9/16	26 5/8	14 5/8	14 7/16	3/4	212	62	1079
24 1/8	12 1/8	6 1/8	1/2	1/2	25 5/8	14 5/8	8 1/2	3/4	130	61	1080
26	10 1/4	10 1/2	1/2	1/2	28 1/2	12 3/4	12 7/8	3/4	170	49	1111
*R26	12 1/8	18	9/16	9/16	29 1/4	15 1/4	22 3/16	3	317	86	1082
26	14	12	9/16	9/16	28 5/8	16 5/8	14 7/16	3/4	244	70	1083
27	8 3/4	7	1/2	1/2	29 1/2	11 1/4	9 1/4	3/4	140	52	1084
32	8	8	1/2	1/2	34 5/8	10 5/8	10 3/8	3/4	157	58	1085
32	9	11	1/2	1/2	35	12	13 3/8	3/4	199	65	1086
32	14	6	1/2	1/2	34 1/2	16 1/2	8 3/8	3/4	164	77	1115
L32	14	32	11/16	11/16	35 1/4	17 1/4	33 15/16		791	199	1088

32	14	10	9/16	9/16	34 3/4	16 3/4	12 1/2	3/4	261	97	1087
*L35	6	7	1/2	1/2	37 1/2	8 1/2	8 5/8		137	49	1089
35	10	13	9/16	9/16	38 1/4	13 3/8	15 1/2	3/4	285	89	1154
36	8	8	9/16	9/16	38 3/4	10 3/4	10 3/4	1	193	75	1091
*36	10	10	5/8	5/8	38 3/4	12 3/4	12 3/4	1	271	82	1090
36	12	12	9/16	9/16	38 3/4	14 3/4	14 1/2	3/4	305	97	1092
*L38	12	12	5/8	5/8	40 3/4	14 3/4	13 3/4		336	86	1094
38	10	10	5/8	5/8	41	13	14 3/8	2 1/2	286	130	1093
42	8	8	5/8	5/8	45	11	10 5/8	3/4	243	82	1095
*L43	9 1/2	11	5/8	5/8	45 7/8	12 3/8	12 3/4		324	86	1096
L44	13 1/2	14	5/8	5/8	46 7/8	16 3/8	15 3/4		445	109	1097
48	7	8 1/2	9/16	9/16	51	10	12 1/4	2	259	75	1098
*L48	7 1/2	14	5/8	5/8	50 7/8	10 3/8	15 3/4		392	83	1099
52	8	8 1/2	9/16	9/16	54 3/4	10 7/8	12 1/4	2	285	96	1142



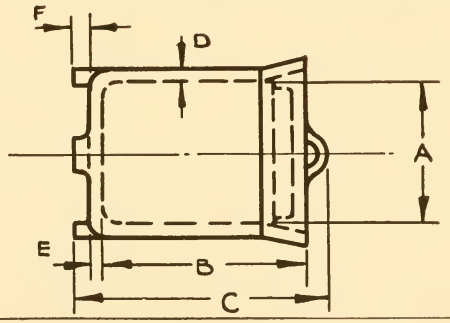
*THESE HAVE RIBS ON SIDE OF BOX BUT CAN BE CAST WITHOUT RIBS IF DESIRED.
R = RUNNERS INSTEAD OF LEGS.
L = NO LEGS OR RUNNERS

ALL BOXES OVER 14x8x8 WILL HAVE A BEAD 1/4x1 AS SHOWN IN DOTTED.
ALL BOXES 18 LONG OR LONGER WILL HAVE THE REENFORCED LID AS SHOWN IN DOTTED

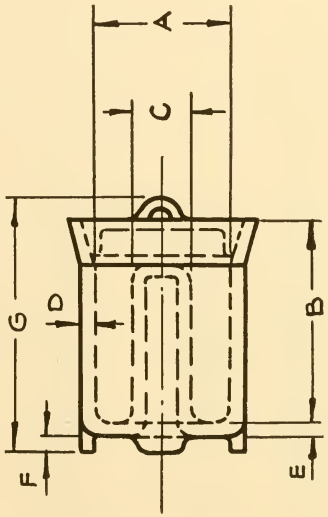
"SEALTITE" HARDENING POTS

A	B	C	D	E	F	Weight of Pot—Estimated	Weight of Lid—Estimated	Pattern No.
All dimensions in inches						In lbs.		
2 5/16	1 5/16	2 3/8	3/16	3/16	3/8	1 1/4	1/2	5031
3 3/8	1 9/16	2 11/16	1/4	1/4	3/8	2 1/4	3/4	5026
4 1/8	2 9/16	3 11/16	1/4	1/4	3/8	4 1/2	1 1/4	5024
5 1/4	1 3/4	2 3/4	1/4	1/4	1/4	5	1 3/4	5032
5 1/2	13 1/2	15 1/2	3/8	3/8	3/4	33	3	5000
6	8 1/2	10 1/2	5/16	5/16	3/4	22	6 1/2	5001
6	10	12	5/16	5/16	3/4	23	6 1/2	5035
6 1/2	13 3/16	15 7/16	3/8	3/8	3/4	36	4 1/2	5002
6 1/2	18 7/16	20 15/16	3/8	3/8	3/4	46	5	5003
7	2 1/2	3 1/2	1/4	1/4	1/4	8 3/4	3 1/4	5039
7 1/2	7 11/16	9 13/16	5/16	5/16	3/4	26	7	5004
8	6 1/2	8 1/4	5/16	5/16	1/2	28 1/2	6 1/2	5005
8	11	13 1/8	3/8	3/8	3/4	41	6	5027
8	13	15 1/8	3/8	3/8	3/4	46	6	5023
9	9	11 3/16	5/16	5/16	3/4	33	8	5007
9	11 5/8	13 13/16	3/8	3/8	3/4	52	9	5008
10	8	10	5/16	5/16	3/4	35	10 1/2	5009
10	10 3/4	13	3/8	3/8	3/4	51	10 1/2	5010

10	12	$14\frac{11}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	1	56	$11\frac{1}{2}$	5011
10	14	$16\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	67	$11\frac{1}{2}$	5012
$10\frac{7}{8}$	$8\frac{1}{2}$	$10\frac{3}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{4}$	44	13	5013
11	$17\frac{1}{2}$	20	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	112	12	5014
$11\frac{1}{8}$	$9\frac{3}{4}$	$12\frac{1}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{15}{16}$	60	11	5015
12	14	$16\frac{1}{4}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{3}{4}$	86	$15\frac{1}{2}$	5016
$12\frac{3}{16}$	9	$11\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	58	16	5025
$13\frac{1}{4}$	$6\frac{3}{4}$	$8\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	55	$18\frac{1}{2}$	5019
$13\frac{1}{2}$	$15\frac{1}{16}$	$19\frac{1}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$2\frac{1}{2}$	122	22	5017
$13\frac{1}{2}$	$16\frac{1}{2}$	$19\frac{7}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$1\frac{3}{4}$	124	22	5018
14	$8\frac{1}{2}$	$10\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	66	19	5020
$14\frac{1}{2}$	22	$24\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	182	23	5028
$15\frac{3}{4}$	$16\frac{1}{2}$	$19\frac{7}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$1\frac{3}{4}$	148	29	5021
28	34	$37\frac{11}{16}$	$\frac{11}{16}$	$\frac{11}{16}$	1	770	120	5022

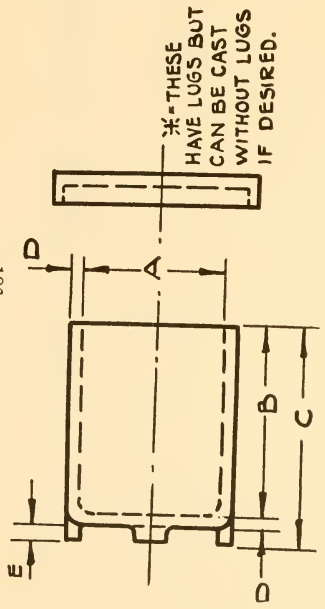


"SEALTITE" HARDENING POTS—CHIMNEY TYPE



A	B	C	D	E	F	G	Weight of Pot—Estimated	Weight of Lid—Estimated	Pattern No.
All dimensions in inches							In lbs.		
10	8 3/4	3 7/8	5/16	3/8	3/4	10 15/16	52	11	6000
10 1/4	9 7/8	3 15/16	3/8	3/8	5/8	11 15/16	60	11	6019
11	10 1/4	4 7/8	3/8	3/8	3/4	11 1/2	69	12	6002
10	11	2 3/4	7/16	7/16	3/4	13 5/16	71	12	6001
11	12	4	3/8	7/16	3/4	14 1/4	82	12 1/2	6003
12	10 3/16	5	7/16	7/16	3/4	12 1/2	87	16	6005
12	15 1/2	4 1/2	7/16	7/16	2	19	122	15 1/2	6013
12	25	6	1/2	1/2	3/4	27 5/16	237	15	6006
12 1/2	11	6 1/2	3/8	3/8	3/4	13 1/4	91	15 1/2	6007
13	15 1/2	4 1/2	3/8	7/16	2	19	124	16	6017
13 7/8	11 11/16	7 1/2	7/16	7/16	3/4	14	126	21	6009
14 3/4	9	7 1/2	3/8	3/8	3/4	11 1/4	97	25	6008
14 3/4	10 1/2	3	1/2	1/2	3/4	12 7/8	122	24 1/2	6018
17 3/8	17	4 7/8	1/2	1/2	1	19 5/8	221	34	6010
22 1/8	12 3/4	12 1/8	1/2	1/2	3/4	15 1/4	267	68	6011
11 3/4	11	6	3/8	3/8	3/4	13 1/4	84	12 1/2	6004

ROUND HARDENING POTS

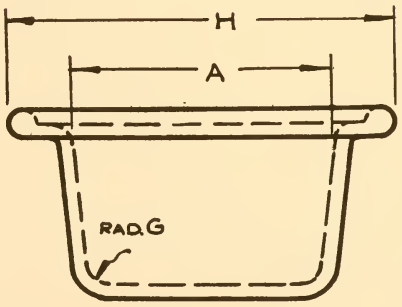


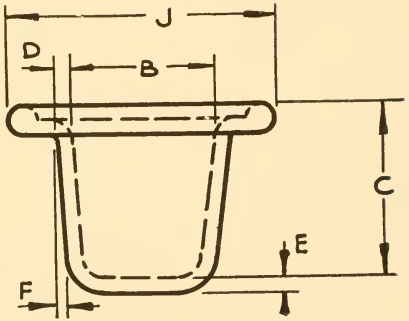
A	B	C	D	E	Weight of Pot—Estimated	Weight of Lid—Estimated	Pattern No.
All dimensions in inches					In lbs.		
7½	5 5/16	6	¼	⅜	17	7	2000
*8	17	17⅜	⅜		61	10	2002
8½	11½	13⅛	⅜	1¼	46	10½	2001
9	13	14⅞	⅜	1½	53	11	2004
10	9	9⅞	⅜	½	44½	13½	2005
*10	12	13⅝	⅜	1¼	57	14	2006
*10	17	17½	½		102	21	2007
12	8	9⅞	⅜	1½	52½	22	2008
12¼	11⅜	12 13/16	7/16	1	79	23	2009
14	8½	10¼	½	1¼	90	39	2010
*16	17	17⅝	⅝		216	43	2011

RECTANGULAR LEAD POTS

A	B	C	D	E	F	G	H	J	Weight —Estimated	Pattern No.
All dimensions in inches									In lbs.	
5 3/8	5 3/8	11 1/2	5/16	5/16	1	1/4	7	7	26	4041
6 3/4	6 3/4	4 7/8	1/2	1/2	1/2	1 1/2	10 3/4	10 3/4	33 1/2	4000
8 5/8	6 5/8	34	5/8	5/8	1/2	1	15 3/8	13 3/8	252	4037
8 7/8	5 7/8	5 15/16	5/16	5/16	3/16	1/2	12	9	25 1/2	4001
9	6 1/4	8 1/4	3/8	3/8	1/2	1/2	11 5/8	8 7/8	37	4002
10	4 1/4	12	3/8	3/8	1/4	3/4	13 1/4	8 3/8	55	4042
11 3/8	5 1/8	4 1/2	3/8	3/8	1/4	3/4	16 1/4	10 1/4	36	4003
11 3/8	5 1/8	5 3/4	3/8	3/8	1/4	3/4	16 1/4	10 1/4	40	4046
12 1/4	6 3/4	10	7/16	7/16	1/2	1	16 3/4	11 1/4	64	4034
14	8	7 3/8	7/16	7/16	11/16	1 1/4	18	12	68	4005
14	12	8 3/4	1/2	5/8	1	1/2	18	16	130	4006
14 1/2	6	7 5/8	3/8	3/8	1/2	1	18 1/2	10	58	4007
18	12	15 3/8	9/16	9/16	3/4	1	21 1/2	15 1/2	180	4008
18 3/4	18 3/4	9 3/8	1/2	1/2	1 7/8	4 1/2	23 3/4	23 3/4	170	4009
19 1/4	13 1/4	8 3/8	5/8	5/8	1	1 1/2	23 1/4	17 1/4	132	4010
19 1/2	13 1/2	15	5/8	5/8	3/4	1 1/2	24 1/2	18 1/2	280	4011
20	10	12	5/8	5/8	3/4	1/2	25	15	167	4012
21 3/4	11 1/2	8 5/8	5/8	5/8	3/4	1 1/2	29 3/4	19 1/2	209	4044

21¾	12	4	½	½	¼	¾	26¾	17	117	4013
24	8	8⅜	7/16	7/16	1	1¼	28	12	105	4014
24	12	12⅜	⅝	⅝	¾	1½	32¾	18	240	4015
24⅜	12⅜	11 11/16	9/16	9/16	½	1 11/16	32	19	220	4047
24½	8½	8⅞	⅝	⅝	¼	½	28	12	157	4027
28	9¾	3⅞	7/16	7/16	¾	1½	31⅜	13⅛	85	4016
30½	18¾	9	¾	¾	1½	3	40	28	375	4017
36	10	5	⅝	⅝	1	1½	39½	13½	150	4018
36¼	14¾	6	⅝	¾	2½	2	37½	23	250	4033
36½	12½	16¼	¾	¾	1	2	44	20	493	4039
37	13	12¾	¾	¾	½	2½	44	20	420	4019
41¼	19¼	9	¾	¾	1	2½	47	25	465	4021
42½	11½	12	9/16	⅝	½	3	47½	16½	280	4020
65	14	8	1	1	½	2	73	22	945	4022
66	22	16½	1⅛	1⅛	¾	7	74½	30½	1330	4023
68	22	9	1	1	1	3	75	29	975	4024
78	18	16	1⅛	1⅛	1	2	86	26	1625	4025

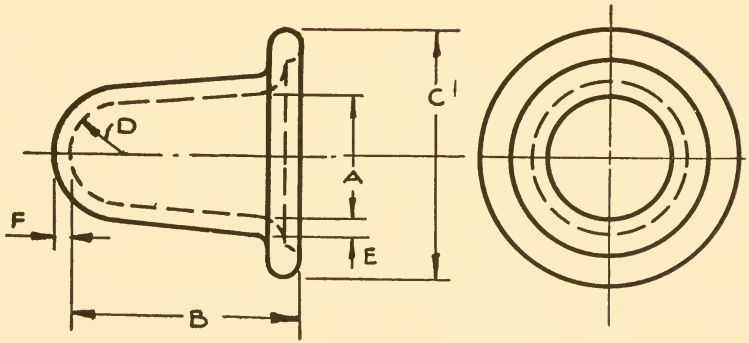




LEAD HARDENING POTS

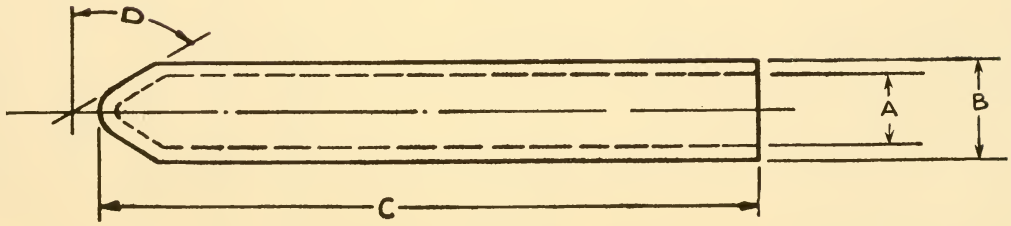
A	B	C	D	E	F	Weight —Estimated	Pattern No.	A	B	C	D	E	F	Weight —Estimated	Pattern No.
All dimensions in inches						In lbs.		All dimensions in inches						In lbs.	
5	8 5/16	9 1/2	2 1/4	5/16	5/16	17	3000	10 1/8	17 7/8	14 7/8	4 9/16	1/2	1/2	97	3027
5 3/8	8	9	2 7/16	5/16	5/16	18	3001	10 3/8	10	15 1/2	4 7/8	7/16	7/16	55	3074
5 1/2	4 3/4	8 1/2	2 1/2	5/16	5/16	10 1/2	3002	11 3/8	10 15/16	16 1/2	5 3/16	7/16	7/16	68	3028
5 3/4	6 1/4	8 9/16	2 5/8	5/16	5/16	13	3003	11 1/2	11 1/8	16 1/2	5 1/4	7/16	7/16	70	3029
6	5 3/8	9	2 3/4	5/16	5/16	11	3004	11 1/2	27 3/8	19	5 1/2	3/4	3/4	285	3069
6	6	8 1/2	3	5/16	5/16	15	3005	11 3/4	14	18	5 7/16	11/16	11/16	135	3055
6	9	9	2 3/4	3/8	3/8	32	3081	12	12 3/8	18 1/2	5 1/2	1/2	1/2	93	3030
6	10 1/8	10	2 5/8	3/8	1/2	33	3006	12	16 3/8	18	5 1/2	1/2	1/2	112	3031
6	11 3/8	11	2 3/4	3/8	3/8	32	3065	12	18 3/8	18	5 1/2	1/2	1/2	122	3049
7 1/4	11	11	3 1/4	3/8	1/2	42	3008	12	49 1/2	15	6	1/2	1/2	310	3082
7 1/4	12	10	3 1/4	3/8	3/8	41	3009	13	13 7/8	18	6	1/2	1/2	104	3032
7 1/2	11	13	3 3/8	3/8	1/2	45	3010	13 1/4	15 3/8	18 1/8	6	5/8	5/8	137	3033
8	6 1/16	11 1/2	3 1/2	5/16	5/16	21	3011	14 1/2	14 7/8	19 1/2	6 5/8	5/8	5/8	143	3043
8	6 7/8	12	3 5/8	5/16	5/16	23	3012	15 1/2	16 1/2	20 1/2	6 15/16	5/8	5/8	173	3035
8	10 1/4	11 1/4	3 5/8	3/8	3/8	34	3013	16	9 3/8	22	7 1/2	1/2	1/2	89	3036
8	10 3/8	14	3 5/8	3/8	3/8	40	3014	16	10	20	7 3/4	1/2	1/2	86	3061
8	11	11 1/2	3 1/2	3/8	3/8	38	3015	16	14 3/8	19	7 1/2	5/8	5/8	135	3078
8	14 1/2	14	3 1/2	7/16	7/16	63	3016	16	14	22	7 1/2	5/8	5/8	159	3053

8	18	11	3 5/8	7/16	7/16	67	3017	16	14 3/8	22	7 1/2	5/8	5/8	161	3063
8	32	11 3/4	3	3/4	3/4	187	3045	16	16	20 1/4	7 1/2	5/8	5/8	167	3046
8 3/16	11 3/16	12 3/4	3 5/8	3/8	3/8	40	3067	17 1/4	17 1/2	22	8 1/4	5/8	5/8	205	3037
8 3/16	17 1/4	12 3/4	3 5/8	1/2	1/2	69	3066	18	12	22 1/4	8 3/4	5/8	5/8	145	3047
8 3/8	7 11/16	11 3/4	4	5/16	5/16	23	3019	18	17 1/4	21 1/2	8 3/8	3/4	3/4	252	3038
9 1/4	20 3/16	13	2 5/8	7/16	7/16	71	3020	18	17 1/2	22	7 1/8	1/2	5/8	195	3079
9 1/2	6 1/4	13 1/4	4 1/2	3/8	3/8	26	3021	19	18 3/8	25	8 3/4	5/8	5/8	223	3039
10	13 1/2	14	4 1/2	7/16	1/2	65	3023	19 1/2	14 7/8	24	9 1/4	9/16	9/16	180	3040
10	15 3/8	15 1/4	4 5/8	5/8	3/4	120	3024	19 7/8	17 3/8	25 1/8	8 7/8	3/4	3/4	267	3041
10	16	13 3/8	4 5/8	7/16	7/16	75	3025	23	20	29 1/4	10 3/4	5/8	5/8	338	3050
10	17	14	4 1/4	5/8	5/8	108	3026								



Self Centering Cam Shaft Carbonizing and Annealing Tubes

A	B	C	D	Weight —Estimated	Pattern No.	A	B	C	D	Weight —Estimated	Pattern No
All dimensions in inches				In lbs.		All dimensions in inches				In lbs.	
$2\frac{15}{16}$	$3\frac{9}{16}$	$32\frac{5}{16}$	30°	32	7114	$4\frac{1}{2}$	$5\frac{3}{8}$	42	40°	87	7104
$2\frac{15}{16}$	$3\frac{9}{16}$	$34\frac{5}{16}$	30°	34	7109	$4\frac{1}{2}$	$5\frac{3}{8}$	49	40°	102	7105
$2\frac{15}{16}$	$3\frac{9}{16}$	$35\frac{5}{16}$	30°	35	7108						
4	$4\frac{3}{4}$	$36\frac{3}{8}$	30°	60	7099						



Pyrometer Protection and Closed End Tubes

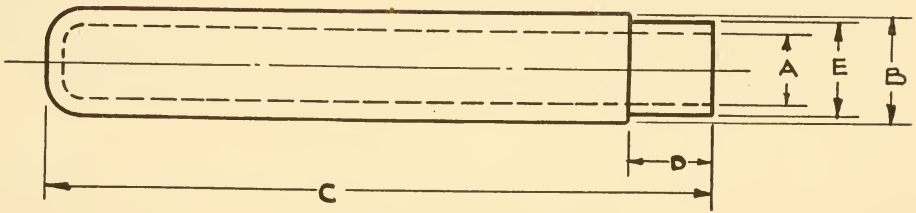
A	B	C	D	E	Weight —Estimated	Pattern No.	A	B	C	D	E	Weight —Estimated	Pattern No.
All dimensions in inches					In lbs.		All dimensions in inches					In lbs.	
3/8	3/4	6			3/4	7000	7/8	1 3/8	12			3 1/4	7037
3/8	15/16	12			3 1/2	7001	7/8	1 1/4	18			4 1/2	7038
1/2	7/8	6			1 1/4	7002	7/8	1 3/8	18			5	7039
1/2	15/16	7 1/2			1 1/2	7003	7/8	1 1/2	18 3/4			6 3/4	7098
1/2	7/8	8			1 1/4	7004	7/8	1 5/16	22			6	7040
1/2	7/8	12			2 3/8	7005	7/8	1 3/8	19	1	1 5/16	5 1/2	7041
1/2	1 5/16	16			6 1/4	7006	7/8	1 3/8	24			6 1/2	7042
1/2	7/8	24			4 3/4	7007	7/8	1 3/8	28			7	7043
7/16	1	18			3 1/2	7008	7/8	1 1/4	30			6	7044
9/16	1	16			3 1/4	7009	7/8	1 1/4	32			6 3/8	7045
9/16	1 1/16	36			6 1/2	7010	7/8	1 7/16	60			19	7047
5/8	1	8			1 1/8	7011	15/16	1 5/16	12			2 1/2	7048
5/8	1 1/16	10			1 3/4	7012	15/16	1 5/16	16			3 1/4	7049
5/8	7/8	7 1/2			3/4	7013	15/16	1 3/8	24			5 3/4	7050
5/8	1	12			2	7014	15/16	1 7/16	31			8 3/4	7051
5/8	1 1/16	18			3 1/4	7015	15/16	1 7/8	48			13 3/4	7052
5/8	1 1/16	27			5 1/2	7016	1	1 3/8	8			1 3/4	7053
5/8	1 1/16	36			6 1/2	7017	1	1 1/2	12			3 1/2	7054

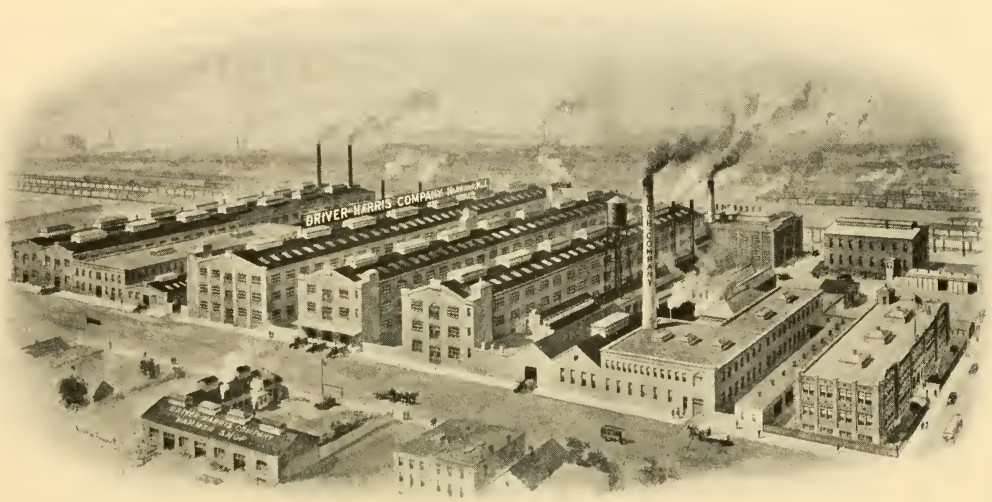
(Continued)

Pyrometer Protection and Closed End Tubes (Cont'd)

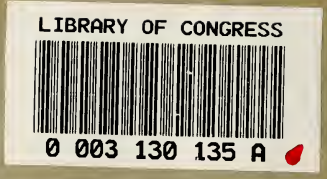
A	B	C	D	E	Weight —Estimated	Pattern No.	A	B	C	D	E	Weight —Estimated	Pattern No.
All dimensions in inches					In lbs.		All dimensions in inches					In lbs.	
11/16	1 1/16	16			2 3/4	7018	1	1 3/8	18			4	7055
11/16	1 1/16	24			4	7019	1	2	22			15 1/2	7056
3/4	1 1/8	8			1 1/2	7020	1	1 1/2	24			6	7057
3/4	1 1/16	12			1 3/4	7021	1	1 3/8	18 1/2			4	7058
3/4	1 1/8	12	1/2	1	2 1/4	7022	1	1 3/8	26			5 3/4	7059
3/4	1 3/8	16			5	7023	1	1 3/8	30			7 1/4	7060
3/4	1 1/8	18			3 1/4	7024	1	1 1/2	48			15 3/4	7061
3/4	1 1/8	24			4	7025	1 1/16	1 7/16	8	1	1 5/16	1 3/4	7062
3/4	1 1/8	27			4 1/2	7026	1 1/16	1 7/16	12			3	7063
3/4	1 1/8	30			5	7027	1 1/16	1 7/16	12	1	1 5/16	3	7064
3/4	1 1/4	36			8	7028	1 1/16	1 7/16	18	1 1/8	1 5/16	4 3/4	7065
13/16	1 3/16	6			2 1/2	7029	1 1/16	1 7/16	24	1	1 5/16	5 1/2	7066
13/16	1 1/4	12			2 3/4	7097	1 1/16	1 7/16	27	1	1 5/16	6	7067
13/16	1 5/32	18			3 1/2	7030	1 1/16	1 7/16	28	1	1 5/16	6 1/2	7068
13/16	1 5/16	19 1/2			5	7031	1 1/16	1 7/16	30	1	1 5/16	7	7069
13/16	1 9/32	24			5 1/2	7032	1 1/16	1 7/16	36	1	1 5/16	8 1/2	7070
13/16	1 5/16	30			7 3/4	7033	1 3/32	1 9/16	18 3/8			5 1/2	7113
27/32	1 9/32	19			4 1/2	7034	1 3/16	1 3/4	6 1/4			2 1/2	7117

27/32	1 11/32	36			8 1/4	7035	1 1/4	1 3/4	18 1/2			6 3/4	7071
7/8	1 1/4	12			2 3/4	7036	1 1/4	2	41 5/8			25	7072
1 1/2	2	20			8 1/2	7073	4	4 1/2	20			21	7084
2	2 1/2	8			5	7074	4	4 3/4	32			52	7100
2	2 1/2	24			12	7075	4	4 7/8	40			75	7093
2	3	33			32	7076	4 1/8	4 5/8	14 1/2			16	7085
2	2 1/2	34			19	7077	4 1/4	5	39			67	7107
2	2 5/8	42			28 1/2	7102	4 3/8	5	20			26	7086
2 1/2	3 1/2	15			18 1/2	7078	4 1/2	5 1/4	29			52	7087
2 9/16	3 1/8	28			23	7079	5	5 3/4	17 5/8			37	7088
2 7/8	3 1/4	8 1/8			5	7080	5	5 1/2	21			27	7089
2 15/16	3 5/8	38			42	7081	5	5 3/4	41			79	7090
3 1/2	4	27			31	7082	5	6	80			200	7091
3 1/2	4	34			33	7083	5 3/8	6	26			47	7096
3 7/8	4 1/2	26			34	7106	6	6 3/4	12			31	7094





Plant of the Driver-Harris Company, Harrison, N. J., where Cast Nichrome and other alloys for mechanical, electrical and chemical purposes are made. The Company also has plants in Walkerville, Ont., Canada, and Manchester, England.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